TECHNICAL FUNDAMENTALS

Pest Control in Agriculture

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CONTENTS

I. THE IMPORTANCE OF PLANT PROTECTION AND PEST CONTROL MEASURES

To secure food for the whole of mankind is an elementary demand but the consequences deriving therefrom are of deep significance. The standard of living has developed unequally in the various countries. Even to-day many millions of men must go short of food. Quite apart from man's desire for better living conditions the demand for more agricultural products will be of cogent significance in the future owing to the growth of the world population during the next decades.

In 1890 the total world population ran to approximately 1,500 millions. In 1961 the 3,000 millions level was reached and with an estimated rate of increase of more than 50 millions per year humanity will double its numbers during the next decades. This means that the ratio of population to cultivated agricultural area will change and that it will be necessary, besides making arable hitherto uncultivated land, to achieve substantial increases in average yields per hectare. If we compare present-day average yields of important cultures with those which must be expected in the year 2,000, if the food supply is then to be secured, we find them in most countries to be partly considerably lower than the yields to be expected.

Is an increase in average yields possible?

Must mankind live in fear of the expected food situation? – Many possibilities to master this situation exist: development and growing of cultures promising success, soil cultivation, fertilizing and employment of modern agricultural machines.

A decisive factor for securing yields is the protection of our agricultural cultures.

Day by day cultivated plants and supplies in store rooms are threatened by thousands of pests and disease pathogens. Every year millions of tons of produce are lost and plants and animals retarded in growth and development or the products derived from these organisms affected both quantitatively and qualitatively. Control of these pests and disease pathogens must become the paramount command for all scientists, technical engineers and farmers responsible for the production of agricultural products.

What is meant by a pest or disease pathogen?

They are animal or plant organisms which damage either cultivated plants or the products derived therefrom. They directly or indirectly influence the health of man and domestic and useful animals.

Innumerable examples of the great danger but also of the large gains obtained after successful pest control could be cited. A few examples will stress the point. However, it must be borne in mind, that the cited figures are not always scientifically exact but often mere estimates.

It may be accepted as a rough rule, that up to one third of the potential crop yields of cultivated plants are lost through pest action between sowing, harvest, storage and consumption. The average world harvest of corn amounts to approximately 590 million tons. Assuming 20 % loss this would be a loss of 118 million tons of corn, that is a loss of food for millions of people. Alone during storage losses amount to approximately 5—10 %, that is 60 million tons. With an average world potato harvest of 200 million tons and again assuming 20 % loss this is a loss of 40 million tons of potatoes. Some years ago losses inflicted on US agriculture by pests amounted to 4,000 million dollars. To this sum must yet be added double the amount accruing from losses due to diseases and weeds.

Such large figures become understandable if one considers that alone a single sparrow destroys 4 kilograms of grain through feeding and other damages accruing incidentally; with thousand sparrows this multiplies to 4,5 tons. Rats, mice and other rodents consume yet far larger quantities, not taking into consideration their higher rate of reproduction. A rat, for example, has a progeny of 800 in one year. Besides losses of cultivated plants and harvest products injurious animals and plant organisms cause considerable additional damages: wood pests, for instance, not only destroy large material values (termites, for example, cause annual damages in the US amounting to 250 million dollars) but also endanger houses.

In addition to the losses due to injurious animals and plant organisms large losses are also caused by weeds. They suppress the growth of cultivated plants and withdraw water and valuable nutrients from the soil. In this case, too, expert control secures a significant rise in crop yields.

The attack of useful animals by pests has less obvious effects, with regard to utilized animal products, however, losses are considerable. Cows kept in stables free of flies give up to 10 % more milk and yield 20—30 kilograms meat extra. Leather from livestock attacked by bot flies either cannot be utilized at all or is of inferior quality.

Another important point is the danger of pests to the health of man and animals. Pests like rats or mice also are carriers of dangerous diseases such as plague, cholera, dysentery, tuberculosis and malaria. The control of malaria mosquitos in Macedonia from 1957 to 1961 reduced the number of persons suffering from malaria from 84,000 to 130.

Thousands of examples more could be cited, many calculations of crop increases after preventing attacks by pests have been made, but the conclusion should be: the battle for values worth thousands of millions, the fight to secure food for mankind now and in future must be waged. By combating pests valuable and urgently needed agricultural products can be won.

II. PLANT DISEASES – PLANT DAMAGES

A. PLANT DISEASE

Every organism is subject to a certain life rhythm. Within organisms chemical and biological processes take place. If disorders develop within an organism, disturbances of the normal course of these vital processes ensue – the organism falls sick. This leads to a decrease in capacity and, in extreme cases, to death.

B. PLANT DAMAGE

Apart from disturbances of vital processes followed by disease, cultivated plants can be affected after attacks by pests, which, in most cases, are not followed by actual changes in the physiological processes. The plants are damaged and utilization is reduced owing to the aforementioned damages.

C. DISEASE SYMPTOMS AND FORMS OF DAMAGE

In consequence of diseases or damages caused by organisms symptoms show on cultivated plants which allow certain conclusions as to their cause. However, positive determination of the disease is in most cases possible only after finding the causative organism. Knowledge of the symptoms caused by pests and disease pathogens is of eminent importance because pin point control of a pest is only possible after an exact diagnosis of the disease and pest.

Important disease symptoms

Wilting

temporary wilting	temporary shortage of water
total wilting	absolute shortage of water, damage to or blocking of water ducts within the plant following destruction of tissue by bacteria or fungi or damage by animal pests

Discolouration	
total discolouration	absolute absence of light; virus attack
partial discolouration	effects of cold; virus attack
spot formation	attack by bacteria or fungi
Rot	
dry rot	usually attack by fungi
wet rot	usually attack by bacteria
Death	
dropping of plant organs	cold; drought; virus attack
death of entire plants	cold; drought
Changes in shape	
leaf rolling, leaf curling	virus attack
distortions of organs and plants	attack by fungi; sucking insects
exuberances	attack by fungi and bacteria
organ transformations, new formations (galls)	nematodes; attack by fungi, bacteria or virus
Wounds	attack by fungi
Excretions	attack by fungi and bacteria

Important forms of damage

Wounds	hail; prick wounds by sucking insects
Loss of tissue	
on exterior plant parts	feeding by animals
scraping or gnawing type of feeding	insects, snails and rodents feeding on surface of certain plant parts
pitting	holes in leaves due to feeding by flea beetles
fed-on leaf margins	feeding on leaf margins
skeletonizing	feeding on entire leaf area with exception of the leaf ribs
complete defoliation	entire plants or plant parts are eaten off
within the plant	
mining	feeding on interior leaf tissue between both leaf surfaces
boring	boring of galleries in plant parts such as tuber, stem, stalk and fruits

D. CAUSES OF PLANT DISEASES AND DAMAGES

Disease symptoms and plant damages can be traced to certain causes. If these are known counter-measures can be adopted. Such causes can be:

Internal causes

Diseases, which are the expression of usually hereditary pathological vital processes

External causes

Diseases, whose causes are introduced to the plant from the outside. With respect to numbers and the possibilities to protect plants from them these diseases are of far greater significance than diseases due to internal causes.

The external causes may be subdivided into:

Non-parasitic disease causes (inanimate environment factors)

climate (temperature, light, water, wind)
soil factors (soil structure, nutrients, physical and chemical soil properties)
chemicals (flue gases, waste waters, chemical substances)

Parasitic causes

viruses
bacteria
fungi
animals

III. INANIMATE ENVIRONMENT FACTORS AS CAUSES OF DISEASES AND DAMAGES

Control of diseases caused by inanimate factors within the framework of plant protection is also possible, but here quite specific measures, different to those adopted to control animate causative organisms, are necessary. With inanimate factors the cause of disease symptoms frequently is very difficult to establish exactly, control is less direct and preponderantly implemented through agricultural and cultural practices alone. Inanimate causes, like pests, effect physiological changes within the plant.

The following inanimate factors must be mentioned:

- Climate and weather
  - temperature
  - light
  - water
  - air
- Soil and nutrition conditions
  - physical soil properties
  - chemical soil properties
  - nutrient supply
- Chemicals
  - smoke, flue gases
  - waste waters
  - chemical agents

A. CLIMATE

Temperature

Plants can be damaged either by excessively low or high temperatures. It is not possible to put down general limits for such temperatures because every plant species or to a certain extent even every individual plant reacts differently according to its adaptability to temperature conditions. The necessary temperature limits for useful plants which can be grown in northern areas of cultivation lie lower than those for plants growing in tropical regions. By adjusting

themselves to surrounding temperature conditions plants may become adaptable to temperature influences. Disease symptoms caused by excessively low temperatures manifest themselves as disturbance of growth, leaf discolourations, shedding of leaves, wilting or cracks and wounds. Similar symptoms are also observed after exposure to excessively high temperatures: discolourations, wilting, drying up. The causes of these phenomena are physiological plant changes, changes in the internal state of the individual cells (cell plasma) and changes in the capacity to take up water and nutrients.

Light

Plant disease symptoms due to unfavourable light conditions manifest themselves, particularly in the case of light shortage, by formation of weakly coloured plant parts, formation of excessively long shoots and reduced rigidity of cell walls leading to decreased stability of the plants.

Water

Water acts on plants as air and soil humidity, dew, rain, snow, hail or ice. Every plant requires a certain amount of water. On the one hand physiological processes within the plant only take place in the presence of water, on the other hand water is an essential constituent of plants. An excess of water due to high air humidity engenders slim plants with low stability, retards blossoming and ripening, and damages plants, particularly through the roots, which no longer are able to regulate the water supply within the plant, and begin to rot. This is followed by symptoms of withering and slow growth of above-ground plant parts. Apart from the influence of snow, hail, rain or changes in soil or air humidity on plants, the impact of rain drops or hailstones on leaf surfaces can give rise to injuries by perforating leaves, cutting off of plant parts or razing of entire plants or plant cultures. Again, if too little water is supplied to plants, symptoms of wilting and drying up, frequently in conjunction with discolourations, ensue.

The feasibility of growing cultivated plants in the world's areas of cultivation differs in accordance with moisture conditions. These depend upon the ratio of water precipitate to water evaporation and drainage, the latter factors being governed by climatic conditions. Thus, despite an excess of water in tropical regions during the rainy period, the water is utilized only insufficiently because it flows off faster than it is taken up by plants or the soil.

Wind

Air motion acts indirectly by changing water conditions within the soil and plants. It decisively influences the whole climate but also the so-called microclimate, which develops in plantations and within plant communities. Soils and, in a certain sense, plants, too, are dried up considerably by wind. Strong winds or storms (hurricane, tornado, typhoon) cause damages directly and, if acting permanently, affect the shape of plants, retard plant growth or destroy plants and entire plantations (razing, uprooting).

B. SOIL

Physical soil properties

Soil texture is vital to the water and nutrient supply of plants. An unfavourable soil structure (e.g. compressions) jeopardizes water and nutrient supplies and the plants grow only moderately or die

Chemical soil properties

Chemical soil properties comprise the nutrient content of the soil and the consequent soil reaction (acid, neutral, alkaline). Those elements in the soil which are absorbed by plant cells and are vital for their synthesis are of particular importance. The main nutrients which plants take up from the soil are nitrogen, phosphorus, potassium, magnesium, calcium, iron and sulfur. In addition, the soil must contain a number of nutrients which plants need just as badly, but only in small quantities, if they are to flourish. Such nutrients are e.g. copper, manganese, tin, cobalt and molybdenum. If certain nutrients are lacking deficiency symptoms, typical for individual species, appear, which chiefly manifest themselves as lack of colouration, stunted growth, low stability and other phenomena.

C. CHEMICALS

Smoke damages occur after interruption of vital plant processes by flue gases, fumes and vapours, soot and solid mineral constituents emitted by industrial plants and transport installations. Causative factors are chemical substances like sulfur dioxide, ammonia, hydrogen sulfide, chlorine or arsenic. The pattern of damage on plants comprises discolouration, spot formation, holes, shedding of leaves and impairment of flowering capacity. Damages in perennial cultures are more serious than in annually alternating ones.

Heavy damages can also be caused through inexpert application of fertilizers and pesticides. Excessive concentrations, inexpert application of certain agents or carrying out of the treatment at inopportune times or dates are the causes in such cases. The results are discolourations and wilting.

IV. DISEASE PATHOGENS AND PESTS

In contrast to green plants which contain chlorophyll and thus are able to feed themselves autonomously by transforming absorbed inorganic materials into organic compounds (autotrophic feeding habit), animal organisms and plants not containing chlorophyll are dependent upon the supply of organic nutrients from the outside (heterotrophic feeding habit). By feeding on plants or their constituents with abstraction of plant juice, they become plant pests. Organisms, which form colonies on or in other organisms and withdraw juice from the latter for their own nourishment without rendering any services in return are termed parasites. They damage plants not only by depriving them of juice but secondarily also by excreting toxic metabolites.

Phytophages or plant feeders (pests in the actual sense of the word) are organisms damaging plants by inflicting losses of tissue or organs on them or destroying entire plants by feeding.

The following are disease pathogens and pests:

- Viruses
- Bacteria
- Fungi
  - archimycetes
  - phycomycetes
  - ascomycetes
  - basidiomycetes
- Nematodes
- Mites
- Insects
  - biting insects
  - sucking insects
- Molluscs and Vertebrates
  - snails
  - birds
  - rodents

A. VIRUSES AS PLANT DISEASE PATHOGENS

The extremely great danger threatening cultivated plants from viruses and the devastating effect of diseases caused by virus infection are due in the first place to the lingering character of these diseases and secondly to the nature of the pathogen little known for many years. All attempts at finding the disease pathogen "virus" failed for many decades. Not having been found outside infected plants for a long time and – unlike bacteria and fungi – not multiplying on artificial culture media, though transmittable to other plants through the juice of infected plants, "virus" was interpreted in the sense of "poison", "juice", "phlegm" or "infectious agent". Only the development of new chemical and optical methods enabled the investigation of the nature of this disease pathogen. Problems of the chemical composition of viruses prevailed at first. After decades of research it could be shown that viruses are nucleoproteids – proteins similar to those in the cell nuclei of plant cells. Chemically, nucleoproteids are proteins composed of nucleic acids (compounds of nitrogenous carbon compounds with phosphoric acid and a carbohydrate) and proteins (compounds composed of several basic constituents – so-called amino acids). Footing on this chemical knowledge it was possible to isolate such "infectious protein". With press juice of infected plants it proved possible to reproduce the identical disease by transferring minute quantities onto healthy plants.

Parallel to the chemical identification of these disease pathogens it was attempted in tedious research to make them visible to the human eye. This proved possible only after constructing modern optical instruments such as the electron microscope. During the investigation of viruses causing plant diseases it was found that they usually are either spherical or rod-shaped. A virus disease of tomatoes is an example of the first-mentioned type and a virus disease of tobacco of the second.

Owing to the difficulties in identifying viruses with regard to their chemical and morphological properties it has up to now not been possible to introduce a proper system of denomination. Thus these disease pathogens often became known under simple names, usually that of the attacked host plant or, when attacking more than one plant, by the name of the plant and an appended letter or number (potato-X-virus, potato-Y-virus). However, with increasing numbers of viruses being identified as disease pathogens on certain plant species, the lucidity of this system of denomination suffered. Hence one strives to introduce a binary nomenclature analogous to that for bacteria, fungi and higher animates and based on the shape, chemical composition and physical and infectious properties of the virus concerned, the first name denoting the genus, the second the species. Footing on the types of organism attacked by viruses we differentiate three virus groups:

Viruses attacking bacteria: bacteriophages
Viruses attacking plants: phytopathogenic viruses
Viruses attacking animals: animal pathogenic viruses

Following infection with viruses plants frequently exhibit mosaic-like spots. During the further course of the infection more or less extensive areas of tissue begin to die (necrosis). Growth anomalies, especially curling, occur frequently. Stunted growth, signs of degeneration and canker-like exuberances also are possible consequences of virus infection.

Knowledge of the possible ways of virus transmission is of extreme importance for selecting control measures. Transmission is primarily possible through animals or mechanically, the first-mentioned way being of eminent importance for disease control. Transmission by animals is effected primarily by insects, especially sucking insects like aphids, leaf hoppers and bugs. During the act of sucking these insects imbibe virus-containing juice of infected plants with their suckers and transfer the virus on to healthy plants during the act of stinging. Transmission of viruses, which loose their power of infection if retained within insects for longer periods of time, must take place immediately. On the other hand, certain types of virus must stay within insects for longer periods and enter the blood via the stomach or the intestines before being excreted through the salivary gland together with saliva during the act of sucking.

The major way of mechanical transmission of viruses is through contact of healthy plants with parts of infected plants, especially when the former have small wounds allowing the viruses to enter.

Transmission by man or implements is effected during tillage of plantations.

Since direct virus control is in practice not possible in the same way as for other disease pathogens, emphasis is placed on measures preventing virus transmission from plant to plant. The simplest method of control is to remove infected plants. Indirect chemical control of virus diseases, which helps to exterminate virus-transmitting insects, is of great importance.

"Swollen shoot", a disease seriously threatening yields from cocoa plantation is also caused by a virus. The infection can be recognized by a discolouration or spotting of foliage, which differs in appearance with the leaf age. Young leaves, not yet deep green in colour, exhibit red lines along the leaf veins or a fading of the colour of the latter. Older, green leaves exhibit a net-like pattern of red spots and the leaf veins are marked. The oldest and toughest leaves do not manifest these phenomena. They yellow gradually. There may be colour changes on the fruits, too, but these are frequently only weakly developed. Owing to abnormal growth of tissue swellings develop on the twigs and the main and subsidiary roots. With the disease persevering the tips of the shoots turn dry, the leaves drop and the whole tree perishes. This is disease caused by various virus strains. Discovered in Ghana in 1936 it has since spread across the whole area of cocoa cultivation in West Africa and has also been observed in Indonesia, Ceylon and Trinidad. Mealy bugs are the disease vectors. They take up the virus when sucking, especially on young shoots and despite their low mobility spread it rapidly by wandering onto branches of neighbouring trees. Mechanical dissemination, too, plays a decisive role. Certain cola species are the host plants of the viruses concerned. Eradication of these host plants in the neighbourhood of cocoa plantations and systematic

destruction of all infected cocoa trees are the best ways of combating the disease. Control of mealy bugs with chemical agents also helps to reduce infection (see colour plate I).

In all zones of cultivation of tobacco virus diseases are no rarity. The losses incurred are not suffered through a reduction of yields but through a serious lowering of the quality of the crop, especially in the case of brands grown for the production of wrappers and binders. The disease symptoms are manifold: young leaves begin to curl and to show a yellow colouration and the colour of leaf veins fades; when the leaves grow they exhibit a light and dark green colouration due to the uneven synthesis of the leaf dyes and changes in the shape of the leaves become visible. The disease symptoms vary with the strain and the leaf age. A large number of plants, members of the *Solanacea* family, in particular, are known to be host plants for the virus in question. In this case, too, mechanical dissemination of the virus predominates. Reports of insects acting as carriers are contradictory, grasshoppers or thrips being mentioned as possible carriers. To prevent infection or to check an outbreak of the disease a very careful and cautious treatment of young tobacco plants (in seed beds!) is necessary, the danger of injuring the plants being greatest during this stage of development. Disinfection of the hands and working utensils is advisable.

Viruses occur practically on all cultivated plants: tomatoes, potatoes, peanuts, citrus fruit, pine apples, bananas, maize, coffee, rice and sugar are attacked by viruses and damaged severely in part.

B. BACTERIA AS DISEASE PATHOGENS

Bacteria, unlike higher organisms, consist of a single cell only. The cells may be spherical or rod- or spiral-shaped. Some of the bacteria possess thread-like appendices, so-called cilia, for the purpose of locomotion. These cilia are fixed either at one end of the cell (polar ciliation) or arranged over the whole surface of the cell (petrichic ciliation). The size of the cells is approximately 1,5—3μ, the pathogen thus being visible with the aid of a microscope only. Bacteria multiply by simple fission (fig. 1).

Bacterial diseases, so-called bacterioses, are usually caused by the penetration of bacteria into injured plant parts. By excreting certain chemical agents bacteria break up cell unions, loosen them or kill part of the cells.

This is followed by decay of plant parts, the infected plant tissue turning into a soft pulpy mass. Such disease symptoms are termed "wet rot".

Some bacteria penetrate deeper into the tissue, reaching the water ducts within the plant and the plant vessels and destroy this tissue. This leads to blocking of the vascular system. The exhibited disease symptoms, known as "vessel bacteriosis", lead to an interruption of the sap flow within the plant, followed by wilting and death ("bacterial wilt").

Certain bacteria, after penetrating into the plant tissue, stimulate the latter to abnormal cell fission and cell multiplication, causing cankerous and goiter-like exuberances.

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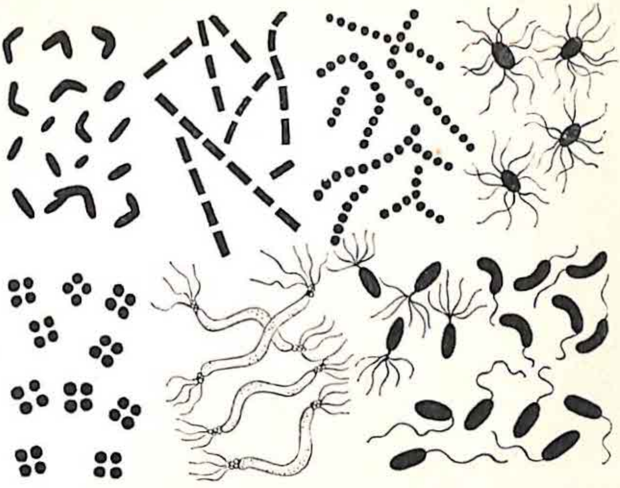


Fig. 1
Types of bacteria

Bacterial attack on overground plant organs (foliage) is usually characterized by encircled spots on the leaves with coloured borders. A potato disease, called "slime disease", also known as "brown rot" giving rise to symptoms of rotting is caused by the bacterium *Pseudomonas solanacearum E. F. Smith*. Occuring predominantly in America, this disease is of eminent importance in tropical countries. The disease is met with in nearly all countries and continents, viz. Italy, Portugal, North-, South- and Central America, Africa, Japan, China, Indonesia, New Zealand, India, Ceylon and Australia. In countries with more severe climate the disease is not widespread. Up to now it has not been identified in Germany and Scandinavia. Besides potatoes it also attacks tomatoes, tobacco and bananas. Following infection potato tops turn yellow, shrivel and the leaves die. The plant stems also exhibit these symptoms. After penetrating into the stem the bacteria wander downwards and form colonies in the interior vessels, the pith and rind parts. This is followed by a brown colouration of the vessels. With the bacteria penetrating deeper the roots, stolons and even the tubers are infected. The tuber vessels, which in potatoes are arranged in an annular pattern, also turn brown. In cases of heavy infection of overground plant organs the tubers either do not develop at all or remain puny. When bisecting infected tubers or stems a dirty brown or grey slime oozes out of the brown zones within the cross section.

The infection of the plants with bacteria primarily takes place at plant wounds. Insects also act as carriers and disseminate bacteria. Control measures must be directed in the first place at the destruction of infected potato shrubs and cool storage and early consumption of infected potatoes. Infected specimens should not be used as seed potatoes. Agrotechnical measures, such as crop rotation (no solanaceae as succeeding crops, but rather cotton or corn) and

destruction of all weeds serving as host plants for the pathogen should be employed. Implements, such as knives, used during work in the cultures should be disinfected with formalin or boiling water. Tomato seeds should be disinfected with mercury compounds.

Tomatoes suffer from a bacteriosis similar to brown rot, the pathogen being *Corynebacterium michiganense (E. F. Smith) Jensen.* The disease symptoms may at first be mistaken for those described above, wilting also being observed, but its progress from pinnule to pinnule is slower. Often the leaves curl up forming little cones. Sometimes wilting is observed on one side of the stem only. A cross-section reveals cavities formed after destruction of the interior stem tissue by bacteria. In this disease, too, the vessels frequently are coloured brown, brown spots also being observed on the fruits of infected plants. Since the bacteria are able to advance through the vascular system right up to the seeds of the fruit dissemination of the pathogen by the seeds is easy. Seed disinfection is, therefore, an important method to check the disease. 100 % destruction of all infected plants is the best control measure (see colour plate II).

A bacteriosis giving rise to cankerous exuberances, caused by *Agrobacterium tumefaciens (Smith et Townsend) Conn*, occurs particularly on fruit trees, berry bushes, but also on turnips, vines and eucalyptus trees. These exuberances, known as crown galls, small, soft and yellow-coloured at the beginning, rapidly grow to considerable size. Later still, they turn brown and hard through lignification. With new galls developing on old ones exuberances the size of a child's head may be formed. In this disease, too, the bacteria penetrate into the plant interior through wounds, however, in this case the tissue in the interior does not suffer destruction, the cells being stimulated to accelarated fission instead. Infection is particularly serious for young plants, because blocking of the water transport (up to 80 %) by gall formation leads to minimal increases in growth, development of small tree crowns, dwarfed growth, premature ripening and low yields (fig. 2).

As examples for uncounted bacterioses of cultivated plants the following may be cited:

Phytomonas ananas Serrano:	causing fruitlet black rot of pineapple
Xanthomonas vasculorum (Cobb) Dowson:	causing gumming disease or gummosis of sugar cane
Xanthomonas albilineans (Ashby) Dowson:	causing leaf scald of sugar cane
Xanthomonas malvacearum (E. F. Smith) Dowson:	causing bacterial blight, stem blight, angular leaf spot of cotton
Pseudomonas tabaci (Wolf et Foster) Stevens:	causing tobacco wild fire

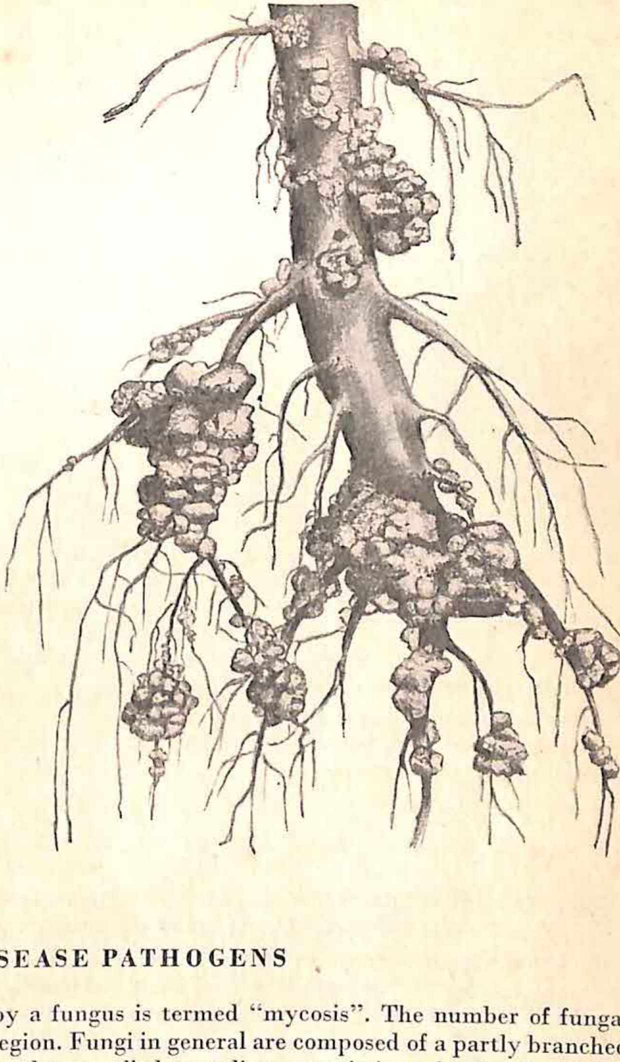


Fig. 2. Cankerous exuberances caused by bacteria

C. FUNGI AS DISEASE PATHOGENS

A disease caused by a fungus is termed "mycosis". The number of fungal disease pathogens is legion. Fungi in general are composed of a partly branched network of filaments, the so-called mycelium, consisting of colourless veins which, developing from spores, cover or penetrate into plant parts. The mycelium filaments invade plant cells depriving them of nutrients. In certain cases the mycelium is visible as a thick coating on the upper or under side of leaves, but often this is possible only with the aid of a microscope. In the latter case the spores of the fungi, which serve as sexual and asexual reproductive cells for multiplication, dissemination and hibernation, also can be seen. The shape of the spores is extremely variegated: round, elliptical, straight, curved, mono-

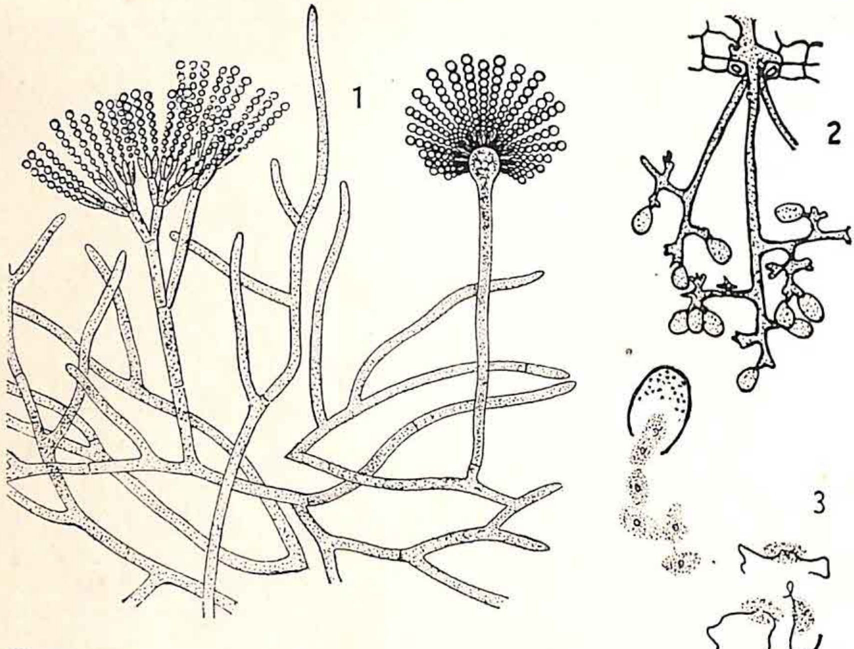


Fig. 3. Development forms of spores
1 sporophore (abstricted at the end)
2 sporophore (projecting from lower leaf side)
3 spore case (release of zoospores)

cellular or multicellular, but always characteristic for the various species of fungi. These spores are formed by swelling and abstriction of the ends of indi- vidual mycelium filaments or their characteristic out-growths, the so-called sporophores (fig. 3). Several species do not form their spores in the open but within cells of various shapes, the so-called sporangia. In these the spores are formed, in some instances in great numbers, and ejected when favourable con- ditions reign. Certain species of fungi which spread predominantly in moist media possess spores fitted with cilia, for the purpose of locomotion. These are termed zoospores. Again, in some cases the sporangia contain only a certain fixed number of spores e.g. four or eight, and usually possess a tubular shape. These spore tubes may be either bowl-shaped and lying in the open or sub- merged and closed (fig. 4).

Spores germinate either immediately or after a certain time with formation of mycelium filaments. Under unfavourable weather conditions certain types

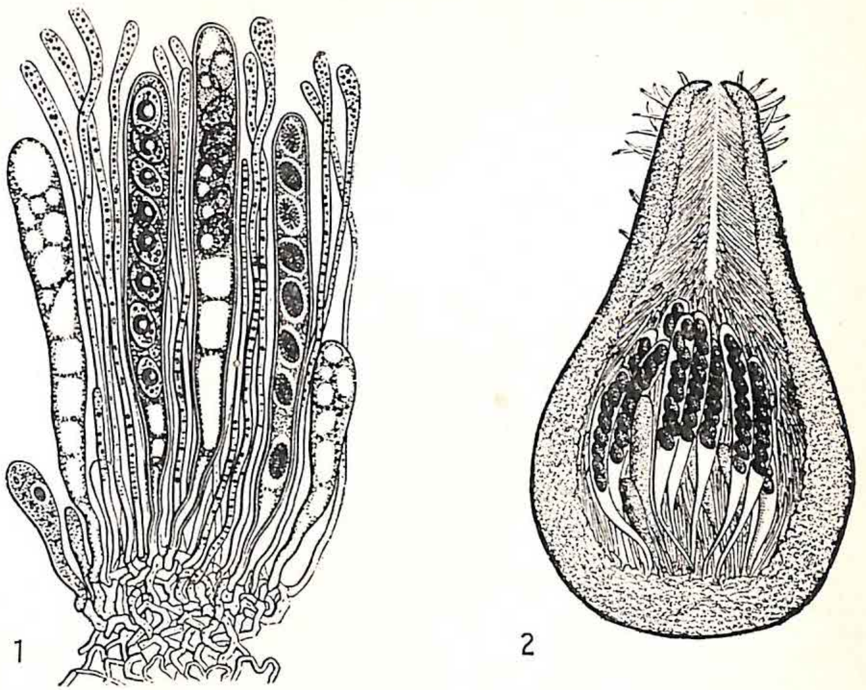


Fig. 4. Development forms of spores
1 flat asci   2 encased asci

of spores are formed which are able to withstand long periods of cold or drought (permanent spores). Spores are spread by wind, water and animals. Dissemination can be checked by destroying all fungus-infected plant parts and residues or by not using spore-carrying seeds for sowing purposes.

Fungi can be controlled with chemical agents, so-called fungicides, both on plants and seeds.

Fungal disease symptoms usually manifest themselves as discolourations, wilting or death of individual plant parts or entire plants, the latter being frequent when the plant roots are affected by fungi. Upon infection of above-ground plant parts discolouration and spot formation become visible, at the beginning often only in a few places. Sometimes distortions, swellings and other changes of shape preceed plant death.

Depending upon the type of spore formation, mycelium structure and the different ways of reproduction the fungi are sub-divided into several groups:

(1) Archimycetes

This group contains the simplest types of fungal organisms. They do not possess a fungal mycelium. The spores, being zoospores, are free and mobile and penetrate into plant tissue through the soil. After formation of new sporangia in the plant tissue zoospores again develop. Under certain environment conditions permanent spores also may be formed, which remain infectious in the soil for longer periods of time.

The following may be mentioned as examples for this type of fungi:

Plasmodiophora brassicae Wor.:	a cabbage disease with exuberances on the roots
Olpidium brassicae (Wor.) Dang.:	attacks young cabbage plants at the stem base, kills the cells and the seedlings collapse
Synchytrium endobioticum (Schilb.) Perc.:	the pathogen of potato wart, causing exuberances on potato tubers

These fungi are chiefly controlled by agrotechnical measures (crop rotation, cultivation of resistant varieties).

(2) Phycomycetes

This group of fungi forms partly branched, tubular mycelium filaments without diaphragms. The most important representatives of this group are

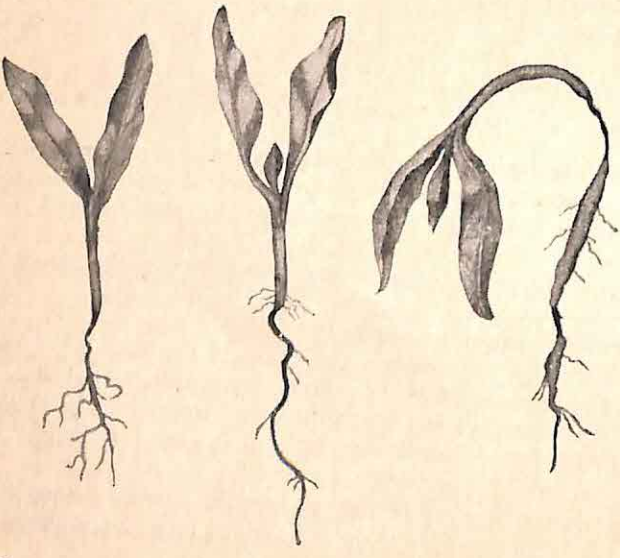


Fig. 5. Root rot of seedlings caused by *Pythium de Baryanum*

parasites known as "downy mildew", which, unlike "powdery mildew", form their mycelia within plants, the mycelium ends, being sporophores, showing on the lower leaf sides only.

Downy mildew species also occur on the roots of young plants. The upper root parts usually assume a dirty-grey colour, the root tissues shrivel turning brown and the plants collapse. Such fungal diseases often lead to incomplete emergence and total destruction of plant cultivations. Examples for this type of fungus infection are the black leg disease and root rot of turnips and tobacco caused by the fungus *Pythium de Baryanum Hesse* (fig. 5) or root rot of sugar cane, which has spread to all areas of cultivation of this plant, caused by the fungus *Pythium arrhenomanes Drechsler*. Such fungal diseases frequently occur on moist sites, because within the development cycle of these fungi zoospores form, which reproduce rapidly and in masses in moist media.

Similar symptoms of decay are caused by the wide-spread fungus *Phytophthora infestans (Mont.) de Bary* – (potato blight). Spots form on the foliage of infected plants which turn black with signs of rotting. Since the fungus also invades the tubers spots of varying size appear on the skin of potatoes. After bisecting a potato brown-coloured marginal zones become visible (fig. 6).

Phytophthora palmivora Butler is the pathogen of bud rot of coco palms and the plants die.

Peronospora tabacina Adam, causing blue mould of tobacco, is another pathogen well-known for years in America and Australia and spreading rapidly across Europe in recent years. On the upper leaf sides first yellowish, later brown spots and on the under side a fur of fungus with a bluish hue become visible. Due to the rapid dissemination of the fungus this disease pathogen causes extensive damages to tobacco plants both in seed beds and in field cultures (fig. 7). Another dreaded downy mildew disease is mealy pod on cocoa fruits *(Trachysphaera fructigena Tabor et Bunting)*.

(3) Ascomycetes

From spores, which in this group are called ascospores, mycelia consisting of mononucleic cells develop. The hypha form sexual organs out of which, following fusion of the nuclei, spore containers – so-called asci – orginate. In these eight ascospores are formed. The fructifications uniting to form asci may be open and cup-shaped *(apothecia)* or closed and globose or flask-shaped *(perithecia)*.

Powdery mildew fungi, well-known parasites of many cultivated plants, also belong to the group of ascomycetes.

A characteristic of "powdery mildew", in contrast to "downy mildew", is the formation of fungus fur both on the upper and under side of foliage. A typical representative, occuring chiefly on grasses (rye, wheat, barley, oats, rice) but also on other cultivated plants such as cucumbers, melons, tobacco, vine and numerous ornamental plants is the fungus *Erysiphe sp.* with its numerous different species (see colour plate III).

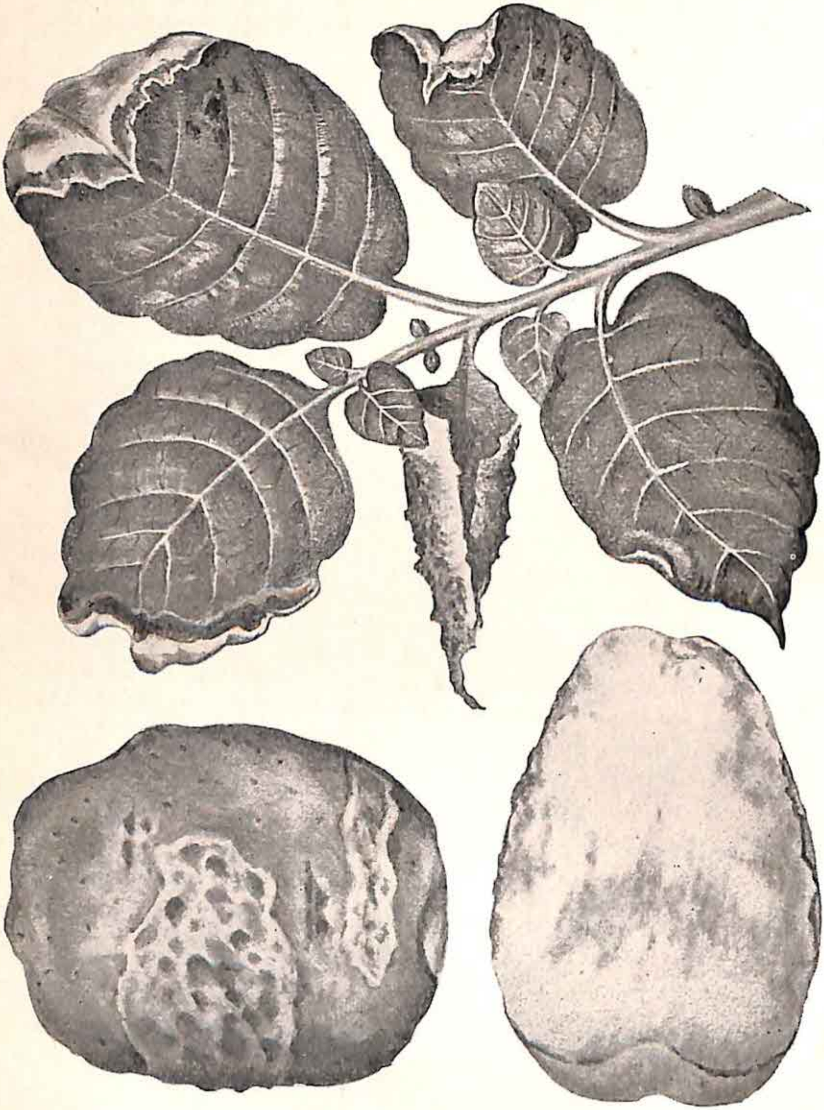


Fig. 6. Potato blight *(Phytophthora infestans (Mont.) de Bary)*, injury on potato tops and tubers

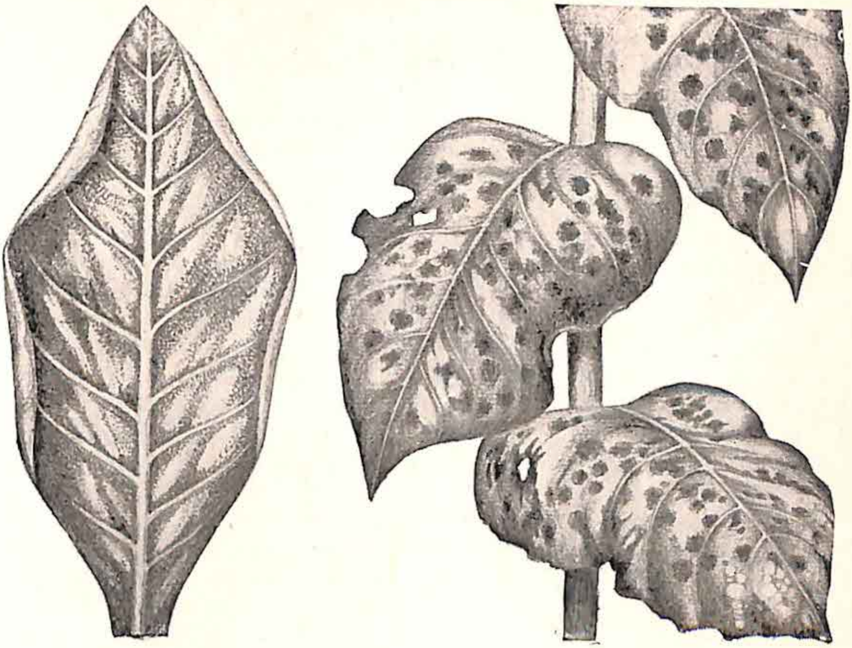


Fig. 7. Leaf injury caused by blue mould

Other important fungi belonging to this group are:

Piricularia oryzae Bri. et Cav.:	rotten neck disease, the most dreaded fungal disease of rice
Mycosphaerella musicola Leach.:	banana leaf spot
Diaporthe citri (Faw.) Wolff.:	melanosis on citrus plants
Glomerella gossypii Edg.:	pink boll rot, cotton anthracnosis
Penicillium sp.:	fungi, causing decay particularly of harvested goods; a whitish-grey fur of fungus may be observed on fruits which turn brown and soft

(4) Basidiomycetes

Out of the spores (basidiospores) a mycelium develops. In contrast to the ascomycetes group four spores are abstricted from a club-shaped swelling of the mycelium, the so-called basidium, at the ends of mycelium filaments.

Two sub-groups are important as disease pathogens: rust and smut fungi.

(a) Rust fungi

Spore colonies frequently exhibit a rusty colouration and are well visible on infected plant parts. A characteristic of these fungi is the production of different spore generations. With many species these spore generations cannot develop on one and the same plant. A change of host is requisite. Since rust fungi can be controlled only with difficulty removal of the intermediate host opens an approach to certain control measures, but does not enable direct control. In practice, chemical control measures are feasible to a limited extent. A certain degree of success in control may be achieved with agrotechnical measures.

In the coffee leaf disease *(Hemileia vastatrix Berk. et Br.)* first light yellow, later dark yellow spots develop on the undersides of the leaves. On older, brown-yellow spots an orange-red powder, the spores of the fungus, can be discerned. Infected leaves are cast off. This disease is wide-spread in all coffee-growing areas, with the exception of South America. *Coffea arabica L.* and *Coffea liberica Bull. et Hiern.* are particularly prone to attack, whereas *Coffea canephora Pierre et Froehner* (robusta coffee) is somewhat more resistant to infection (see colour plate III).

Rust fungi of the genus *Puccinia* (e.g. *Puccinia sorghi Schw.* with *Oxalis* sp. as intermediate host) and the genus *Uromycetes sp.* are particularly important disease pathogens on turnips, peas, beans and other cultivated plants.

(b) Smut fungi

Smut fungi often form their dark, nearly black spores in boil-like swellings. In maize cultures swellings, the size of a fist, can be found on overground plant parts containing the spores of *Ustilago maydis (D.C.) Corda* (corn smut, boil smut). The swellings are caused by the intensive cell formation and cell enlargement following invasion by the fungus. Heavy outbreaks of this disease lead to large harvest losses. Since infection is effected chiefly by soil-borne spores crop rotation and destruction of all infected maize plants is absolutely indispensable. Seeds should be treated with mercury seed disinfectants and sown on previously uninfected plots only (fig. 8).

D. NEMATODES AS PLANT PESTS

Nematodes, also known as eel worms, are small worms with eel-like, wriggling movements living free in water or soil. Nematodes harmful to plants possess a mouth thorn with which they are in a position to prick and subsequently to penetrate into plants. This may take place at the roots (root eel worms) or at the stem (stem eel worms). As a result of the sucking activity of these pests cell injuries, impairment of growth and gall formation occur. With some nematode species the feminine animals are transformed into so-called cysts, enveloping first the eggs and later the larvae, thus enabling the progeny to survive in the soil for years.

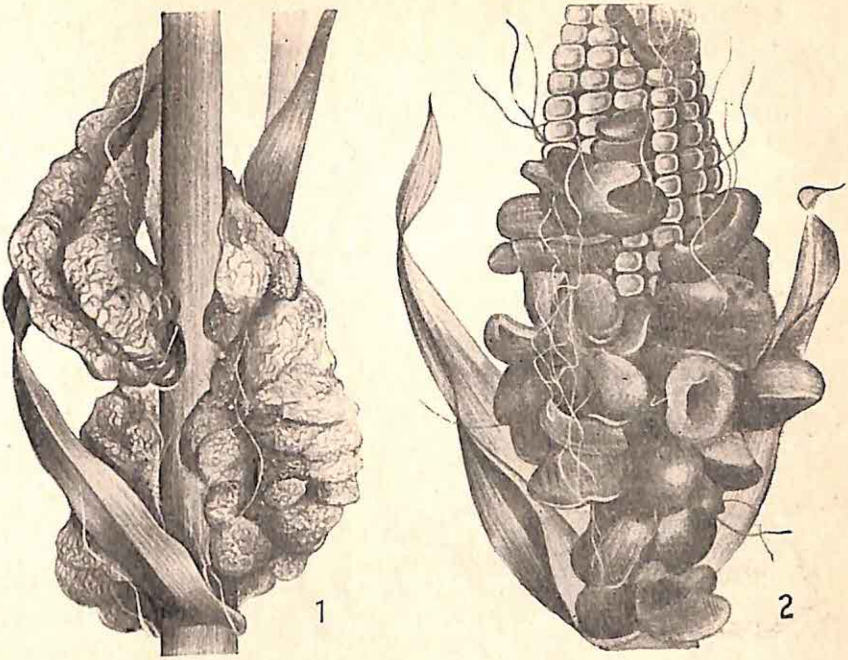


Fig. 8. Corn smut *(Ustilago maydis (DC.) CDA.)*
1 smut balls (spore case) on corn stalk   2 infected corn cobs

Nematodes attack nearly all cultivated plants. Having once gained foot they, as a rule, cause great damages, at times making cultivation on infected areas impossible. They attack potatoes, turnips, corn, tobacco, coffee, cucumbers, tomatoes, citrus plants, cotton, bananas, ornamental plants and other cultures. Owing to root decay and foliage and stem damage nematode-infected plants show signs of wilting and atrophy, the leaves drop off and death of the entire plant may follow. Upon attack by gall-forming eel worms swellings (galls), ranging from pin head to pea size, develop on the roots (fig. 9).

Control of these pests, particularly of root, root gall and stem eel worms, is extremely difficult. Soil disinfection with chemical agents is possible but very expensive and often of limited success only. Thorough destruction of all harvest residues (roots!) and crop rotation are the best measures of control. Stem and leaf eel worms can be controlled with systemic phosphoric acid esters. The most frequently occuring genera with various species are *Heterodera sp., Ditylenchus sp., Meloidogyne sp., Pratylenchus sp. and Aphelenchoides sp.*

Fig. 9. Injuries by root gall eel worms

E. MITES AS PLANT PESTS

These sack-shaped 0.5—1 mm large animals with four pairs of legs injure herbaceous plants and fruit trees in particular, by sucking at the leaves. The leaves first exhibit white, later yellow to brown spots and die. On the under side of the leaves webs are formed which contain first the eggs and later the larvae of these animals.

Spider mites (e.g. red spider mites) occur frequently in fruit cultures but also attack many other cultivated plants such as cotton, coffee, tea, vine, hops and vegetables.

In cases of heavy infestation and neglected control the plants may die already a few weeks after showing the first symptoms. Infestation varies with weather conditions. Under favourable climatic conditions the time of development of one pest generation may be very short, so that several generations (up to 12—16) can be expected in one year (fig. 10). Control of spider mites must be carried out intensively either with dormant sprays containing DNOC preparations and yellow oil or, in the summer, with acaricides or organophosphorus compounds.

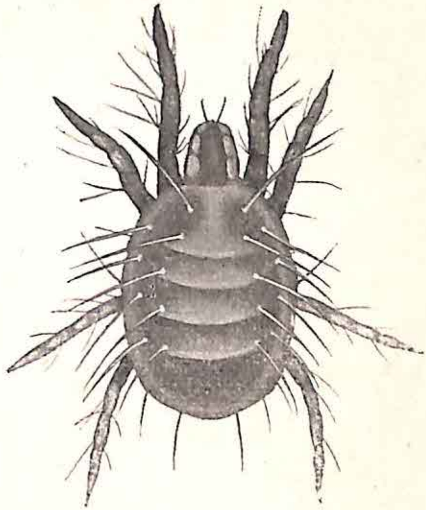


Fig. 10. Spider mite

Control of gall mites *(Eriophyidae)* is especially difficult. These 0.1 mm large animals with only two pairs of legs damage plants by converting plant parts into galls in which they live and feed. Control of these pests of fruit and vine growing must primarily be carried out with systemic preparations.

Fig. 11. Insect body structure

F. INSECTS AS PLANT PESTS

The enormous number of existing insects constitutes the most important group of animal pests of plants. Numerous ways of inflicting injuries, such as penetration of animals into the plant interior, excretion of toxic substances, development of succeeding generations within the plant are possible. The great danger threatening plant cultures from insects is demonstrated by the fact that plant parts are the sole source of food for insects. In cases of mass infestation this may lead to complete defoliation. Insects endanger plants also by acting as carriers of various kinds of disease pathogens (viruses!).

Insects can be recognized by their characteristic build: a body divided into three distinct segments – head-thorax-abdomen. The antennae, eyes and feeding instruments are situated on the head. The thorax is sub-divided into three more or less visible segments, each carrying a pair of legs (fig. 11).

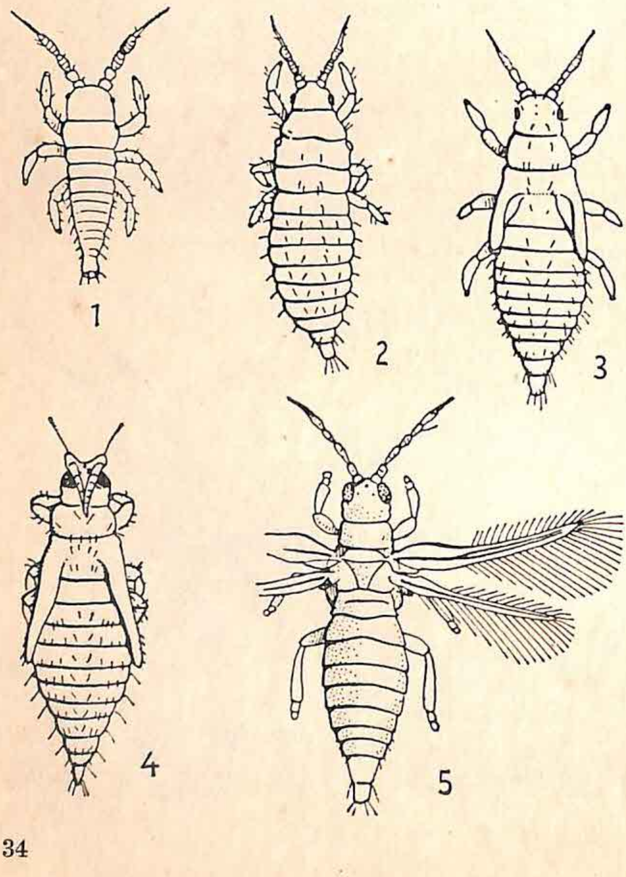


Fig. 12. Stages of development of a thrips

1 young larva
2 old larva
3 pronymph
4 nymph
5 imago

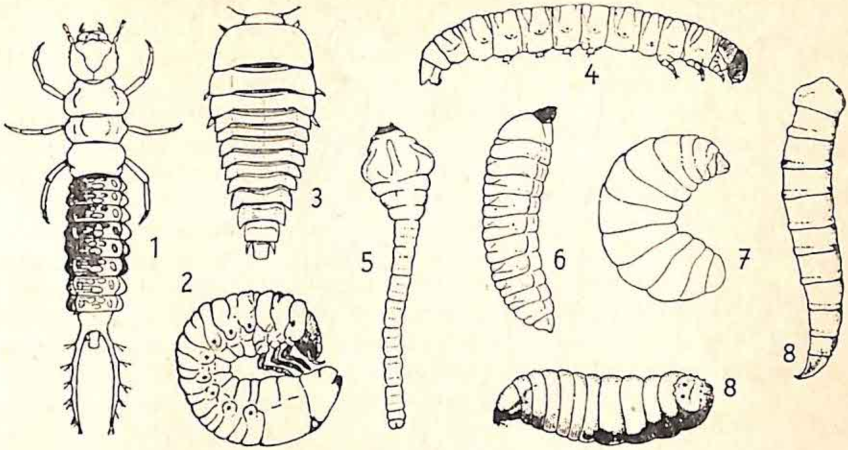


Fig. 13. Types of insect larvae

1 larva of ground beetle
2 larva of a foliage beetle
3 larva of a carrion beetle
4 larva of a butterfly
5 larva of a metallic beetle
6 larva of a snout beetle
7 larva of a bee
8 larvae of flies

Another characteristic of insects is their rhythm of development, the egg stage being followed by one or more stages of development (metamorphosis).

From eggs laid by the female, "larvae" hatch which, in one group of insects, develop directly into the adult insect by repeated moulting. Thrips, leaf hoppers, flea hoppers, aphids, grass hoppers and termites belong to this group of insects (fig. 12). The larvae already closely resemble the actual insects, both being difficult to distinguish (insects with incomplete metamorphosis).

In another group of insects there is a quiescent stage (pupation) between the last larval stage and the actual insect from which the perfect insect emerges after a certain time (insects with complete metamorphosis). In contrast to the first-mentioned insect group the larvae of the latter class being completely different in build do not resemble the adult insect e.g. the caterpillars of butterflies and weevils or the larvae of flies, commonly termed maggots. The differences need not be restricted to the exterior shape only; both forms may have widely differing ways of life. Thus, for example, larvae (caterpillars) of butterflies are dreaded feeding pests, whereas butterflies, with their sucking way of life, are phytopathologically quite insignificant. Vice versa, there are species of insects where both larva and adult insect are pronouncedly dangerous pests, e.g. the larvae of weevils (grubs, wireworms) and the weevils themselves (fig. 13). The pupae of this group of insects lie either exposed or in a web or cocoon and may differ in shape and size. In some of the pupae (pupae of wee-

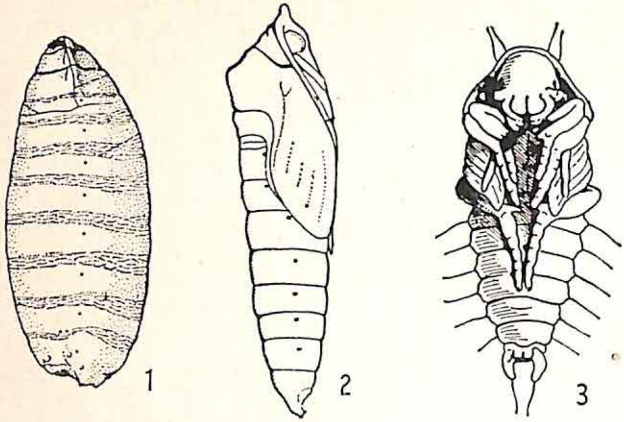


Fig. 14. Types of insect pupae
1 puparium
2 mummy pupa
3 free pupa

vils) certain forms of the ulterior imago can already be discerned, whereas the pupae of flies and gnats do not show the smallest trace of a form of the insect developing subsequently (fig. 14).

The pattern of damage characteristic of insects is governed by the way of teeding of these animals or, to put it an other way, by the mode of action of fheir mouth parts (fig. 15). Insects with chewing or biting mouth parts as a

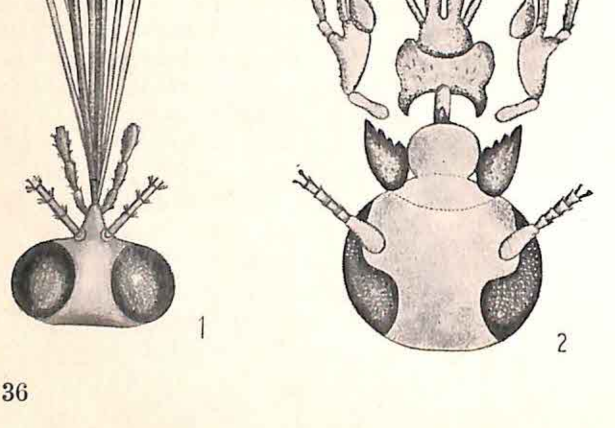


Fig. 15. Mouth implements of insects
1 sucking insects
2 biting insects

rule cause characteristic feeding patterns on plant parts. The process of feeding may take place on the leaves or on plant surfaces and thus is visible to the eye. This can be important for the identification of the pest. The feeding pattern of insects or their immature forms living in the interior of plants also frequently is characteristic but remains hidden till the object – a stem for example – is cut open. Owing to their hidden way of life such pests often can be identified only with difficulty and too late, when the interior of plants has suffered destruction to such an extent that the vital processes are visibly disturbed.

Insect control must be carried out in various ways adapted to their different ways of life. Insects living on plant surfaces can be controlled relatively easily by distributing pesticides on plant parts. The pests imbibe the poison when feeding or are affected by mere contact with the poison. With insects living within plants it is important to get the poison to the insect in the plant or, in analogy to the control of sucking insects, the pesticide must be absorbed by the plant and transported to the seat of the insect.

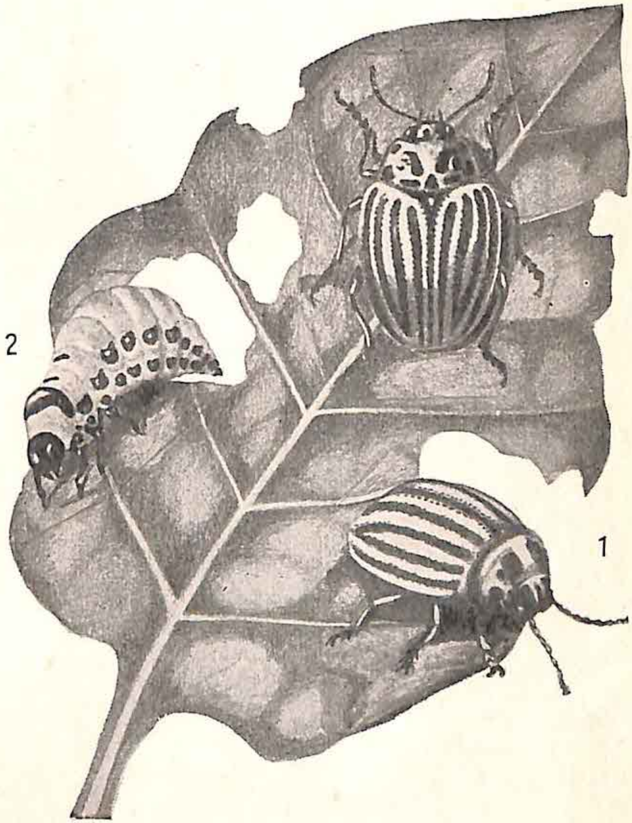


Fig. 16. Colorado beetle *(Leptinotarsa decemlineata Say.)*
1 beetle
2 larva

The number of insects known to be pests being large only a rough survey of these pests and the damages wrought by them can be presented. Only the most important groups, illustrated by a few examples can be mentioned, the distinguishing characteristics being build, reproduction and way of life.

Every plantation of cultures, every single plant may be attacked by a group of biting insects, the weevils, which, by feeding on them, cause great damages. In accordance with their exterior shape and the nature of their damages, which is partly governed by the former, the weevils are sub-divided into numerous families. Their major characteristics are described below and illustrated with a few examples from some of the families.

Chrysomelidae: usually oval-shaped weevils with a metallic lustre, frequently with a brightly coloured body. Both the weevils and their larvae are dreaded leaf-feeders.

One of the best-known examples of this type of insects, also with regard to rapid distribution, is the Colorado potato beetle *(Leptinotarsa decemlineata Say.)*.

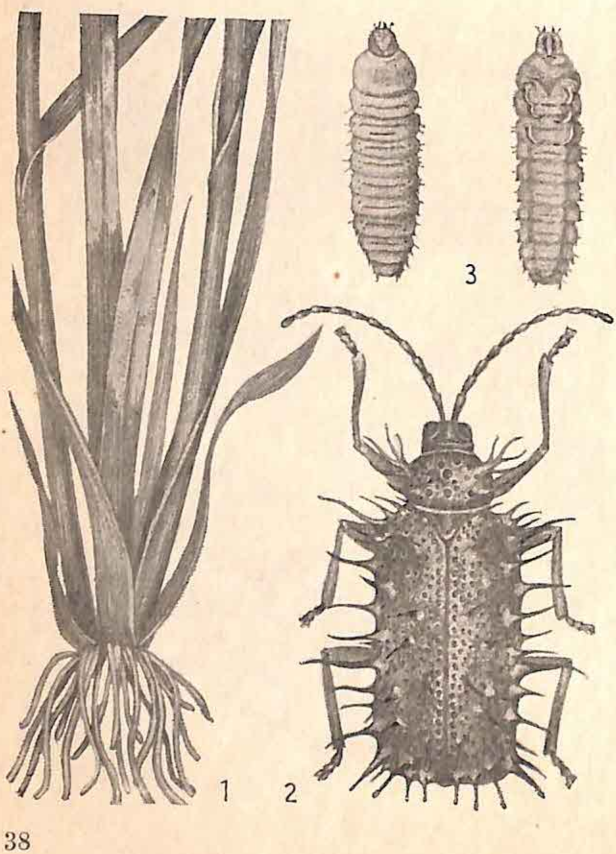


Fig. 17
Rice hispa *(Hispa armigera Oliv.)*
1 pattern of damage
2 beetle
3 larvae

The yellow-and-black striped beetles and the brick-red larvae both are capable of destroying entire potato cultivations (fig. 16).

The 3 mm leaf beetle or armour weevil *(Hispa armigera Oliv.-Rice-leaf-beetle)* distinguished by a metallic lustre and possessing fore wings *(elytra)* covered with small thorns, attacks rice plants both in seed beds and on the fields. The larvae hatching from eggs deposited on the under side of the leaves bore into the latter. The weevils feed on the chlorophyll in the foliage so that the leaves of affected plants exhibit light, transparent stripes. In some of the gradually wilting leaves the larvae can be discerned (fig. 17).

"Flea" beetles *(Halticinae)*, also members of this group, have developed their hind legs into a kind of saltorial leg enabling the animals to jump from plant to plant (fig. 18). They primarily damage young plants of all cultures.

Scarabaeidae: relatively large, clumsy beetles with a thick chitin armour and usually plane-shaped feelers. The larvae of these beetles, known as "white grubs", are particularly dangerous soil pests.

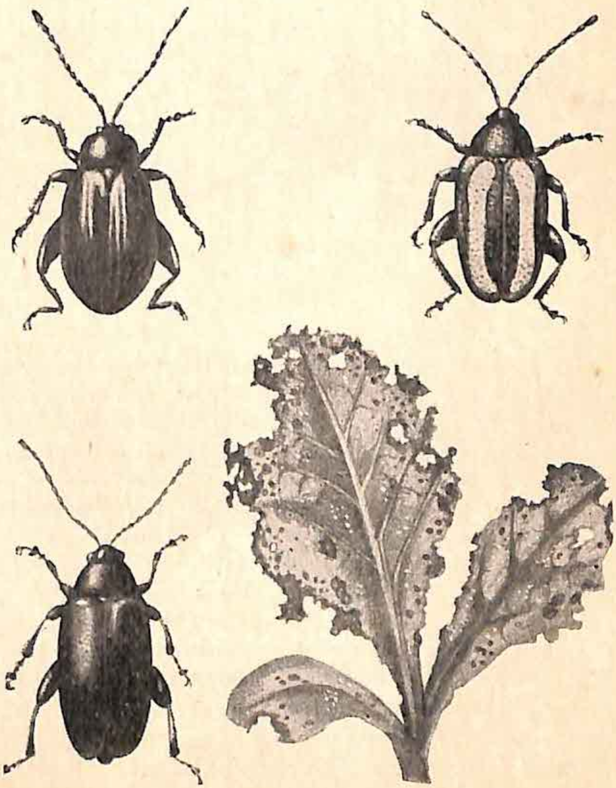


Fig. 18. Flea beetles *(Halticinae)* and typical pattern of damage

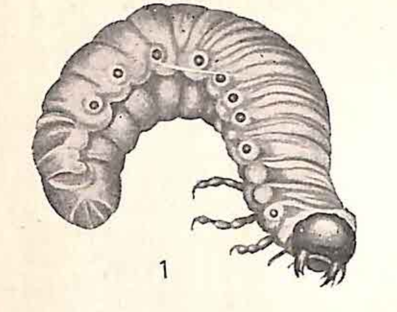


Fig. 19
Rhinoceros beetle *(Oryctes rhinoceros L.)*
1 larva
2 female beetle
3 male beetle

The rhinoceros or elephant beetle *(Oryctes rhinoceros L.)*, a lustrous brown 40—60 mm beetle is a major palm pest. The males carry a 1 cm big scimitar-shaped horn on their heads. The females develop no or only small horns. The beetles penetrate leaf buds or the underside of leaf bases and fibrilize the plant material with their mastication organ. Upon injury of growing points by beetles the palms die. Larvae hatching from eggs deposited on rotten tree trunks grow to be 6—10 cm long, are grey in colour and possess a reddish-brown head. The produced bore holes also facilitate secondary infections. This beetle chiefly attacks coco palms but also jeopardizes other palm species (fig. 19).

Click beetles *(Elateridae)*: the adult beetles of this family are less dangerous than their usually yellow-brown coloured larvae, which are soil pests found in many cultures ("wire worms"). They totally defoliate seedlings but also attack and severely damage older plants at the roots and stem bases. The beetles themselves usually are somewhat elongated in shape and, possessing a special vaulting device, are able to jump (fig. 20).

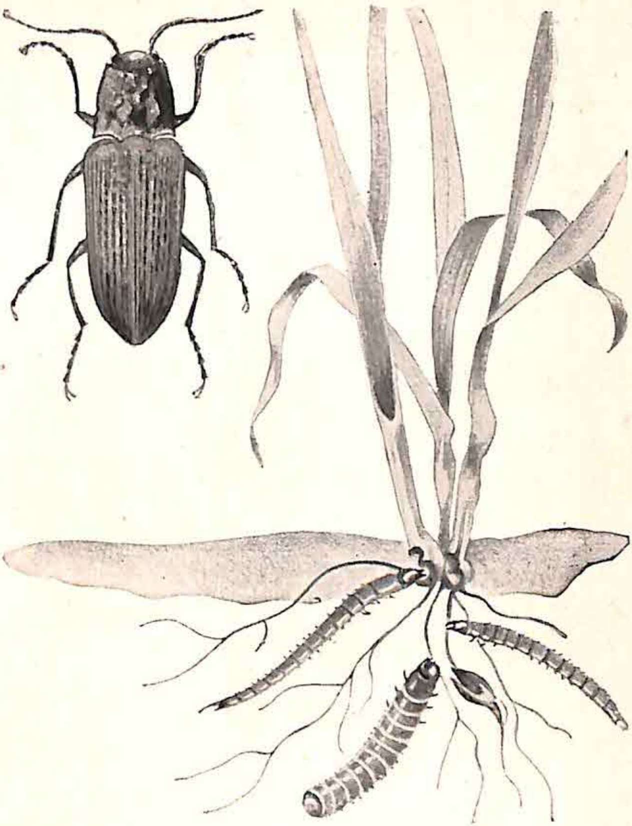


Fig. 20. Click beetles *(Elateridae)* and larvae (wire-worms)

Snout beetles *(Curculionidae)*: A characteristic feature of this family is the front part of the head which is drawn out to a more or less thick snout.

Cotton boll weevils *(Anthonomus grandis Boh.)* which, like their larvae, destroy the tissue of cotton pods and buds are dangerous cotton pests. The females oviposit on the buds and these are fed on by the larvae developing four to seven days later. After 2—4 weeks the next beetle generation is born. Within a single year 4—7 generations must be reckoned with. The infected flower buds turn yellow, harden and drop off. The losses may be as high as 20—40 % of the possible harvest (fig. 21).

Another snout beetle causing young banana plants in banana plantations to perish is the greyish-brown, 1 cm long banana weevil *(Cosmopolites sordidus Germ.)*. It oviposits on the lower parts of the pseudo stem. The hatching larvae bore into the same and mine the tissue (fig. 22).

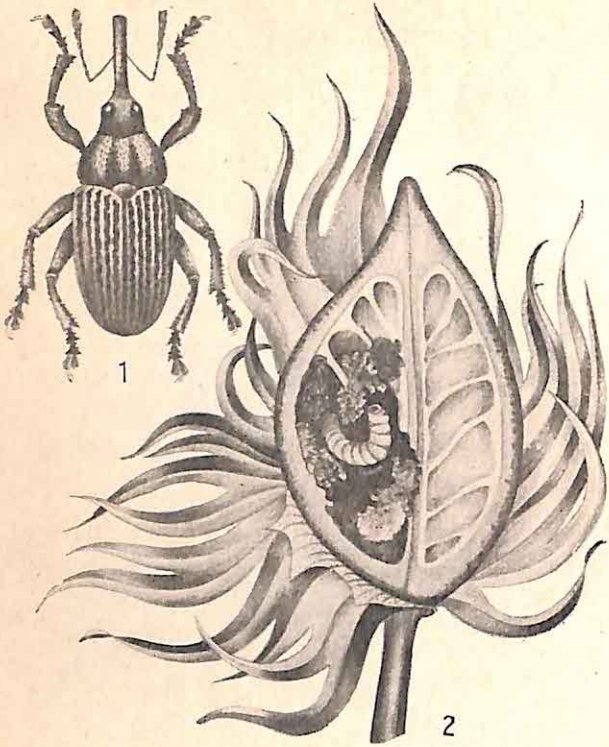


Fig. 21. Cotton boll weevil *(Anthonomus grandis Boh.)*
1 weevil
2 larva in cotton boll

Long-horned beetles *(Cerambycidae)*: the larvae of these beetles bore through the pith of plants down to the wood and cause considerable damage by destroying the interior plant tissue.

The coffee tree is attacked by many species of coffee stem borers; the beetles oviposit just above the soil surface or on other parts of the stem or branches. The larvae at first bore galleries in the raffia and later in the wood. The bark of infected trees cracks. At the points of rupture borings, bore dust and galleries may be observed. Owing to the destruction of the water ducts by mining, the affected trees show symptoms of wilting, which may ultimately lead to death (fig. 23).

Caterpillars of butterflies constitute another large group of pests causing considerable damages with their biting mouth parts. The butterflies themselves, with their sucking mouth parts, are quite insignificant as pests. The larvae are cylindrical in shape, more or less multifariously coloured and partly covered with bristles. Owing to their firm outer layer and their way of life control of these pests is difficult. Observation of the butterflies, their flying time and

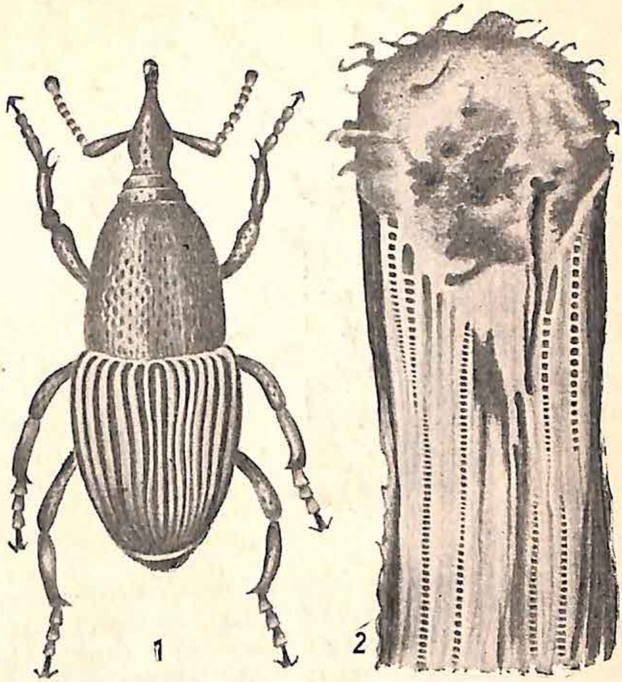


Fig. 22. Banana weevil *(Cosmopolites sordidus Germ.)*
1 weevil
2 gallery bored by larvae

other biological properties are, therefore, of great significance. Caterpillars are found in nearly all plantations. Mass infestation frequently leads to complete devastation of whole cultivated areas. The Egyptian cotton worm *(Prodenia litura F.)* is a case in point. After oviposition by the butterflies greenish, later brown-black caterpillars with yellow stripes, dark warts and short bristles hatch from the eggs. There may be up to 10 generations within a year. The voracity of these caterpillars may lead to complete defoliation of cultures, stems, buds and pods also being affected. Heavy infestation may lead to total crop failure on large cotton areas (see colour plate IV).

Rice stem borers *(Chilo sp., Schoenobius sp., Scirpophaga sp.)* being caterpillars of various butterflies and serious rice pests may cause devastating damages in areas of rice cultivation. Under favourable climatic conditions up to 8—10 generations develop within a year. The caterpillars first feed on the leaf tips and from thence penetrate into the rice stem forming excavations. At this stage, control is extremely difficult or quite impossible. The rice plants wilt, dry up and collapse. Plants developing despite the infection do not reach the flowering stage and the panicles remain empty.

Other serious pests destroying entire buildings and cultures by mass invasion are termites and grass hoppers *(Locusta sp., Oxya sp., Schistocerca sp.)* which

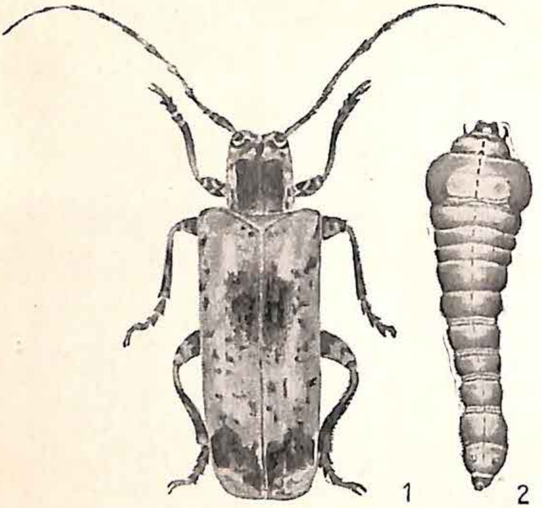


Fig. 23. Coffee stem borer
1 beetle
2 larva

possess biting mouth parts. Termites attack living plants by usually first invading dead plant parts penetrating from there into the juicier parts. When termites attack wood this often cannot be seen from the outside because cracks on the surface are stopped up with little lumps of excrements. Protection measures against these all-devouring pests should preferably be of a preventive nature e.g. destruction of all wood residues or stubbles in plantations, efficient irrigation and soil treatment with chemical agents. Wood should be impregnated with chemicals by dipping, painting or spraying. Apart from their enormous voracity, grass hoppers are particularly dangerous by swarming suddenly and in gigantic numbers followed by invasion of certain regions. Observation of their development, a well organized warning service and systematic control with chemical agents assure a certain degree of success in combating these vor-
acious pests (fig. 24).

A large number of injurious insects possessing sucking mouth parts causes considerable damage by pricking plant parts and withdrawing juice therefrom. With their sucking activity they simultaneously act as carriers of many disease pathogens (viruses) which, after infection, lead to secondary disease symptoms. Aphids *(Aphidae)*, relatively small winged or unwinged insects, are particu-
larly dangerous pests. Attack by these pests may be recognized by phenomena such as leaf rolling, leaf discolouration, gall formation and similar symptoms caused by their sucking activity. The cotton louse *(Aphis gossypii Glover)* causes such aforementioned patterns of damage on cotton. The crop is depre-
ciated both quantitatively and qualitatively. The louse is found in nearly all world areas of cultivation and, being a polyphagous pest, also attacks citrus species and various plants of the *Cucurbitaceae* family (fig. 25). The pineapple

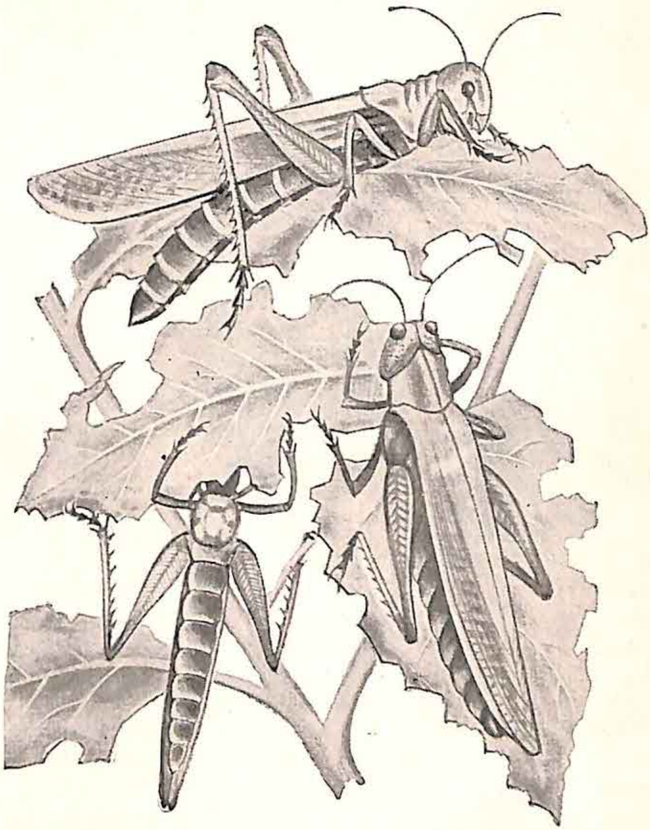


Fig. 24. Grass hoppers

mealy bug *(Dysmicoccus brevipes Ckl.)* whose 2—3 mm thick females are oval-shaped and wax-coated, causes spot formation, leaf changes and symptoms of degeneration on pineapple plants. Occuring all over the world, it has also been observed on oil palms, bananas, ground nuts, cocoa and other cultivated plants (figs. 26, 27). Various aphid types may be recognized by their shield-like cover beneath which they cling to the plants (scales).

The following wide-spread pests also are pests possessing sucking mouth parts: Capsid bugs *(Lygus sp.)* and thrips *(Thysanoptera sp.)*. The former usually possess a flattened body covered by chitinaceous front wings. Bugs of the genus *Helopeltis* infest tea bushes as well as cotton plants, cocoa, mango and cinchona bark.

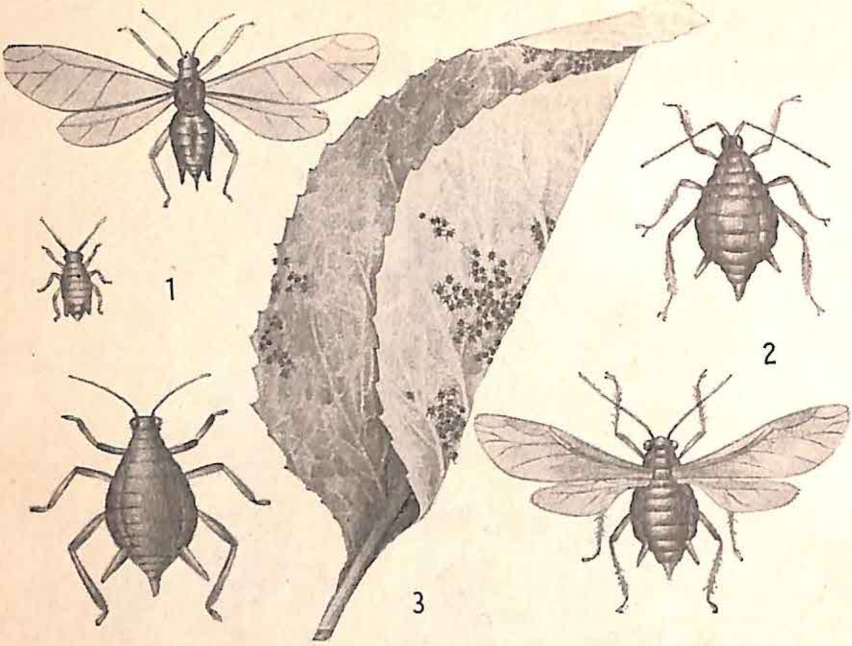


Fig. 25. Aphids
1 cotton aphid *(Aphis gossypii Glov.)* winged and wingless generation
2 black bean aphid *(Aphis fabae Scop.)* winged and wingless generation
3 damage after aphid attack

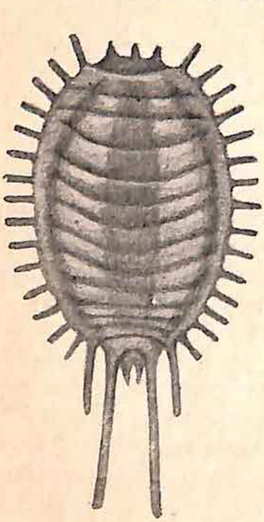


Fig. 26. Citrus mealy bug

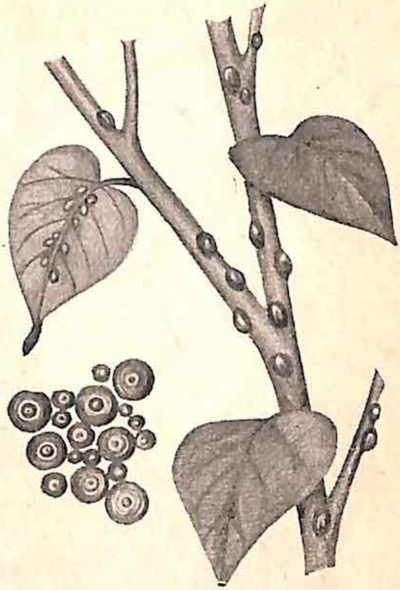


Fig. 27. Damage by scales

Their sucking leads to discolourations, irregular growth and finally to shedding of the foliage (fig. 28). Thrips occur in many plantations and injure stems and leaves by sucking. They also attack ears, panicles and ovaries. This leads to empty panicle and prevents seed formation (fig. 29). Red banded thrips *(Selenothrips rubrocinctus Giard.)*, a dark brown 1—1.5 mm long insect, attacks cocoa but also infests coffee, cola and cotton plants causing both leaf damages leading to shedding of foliage and incompletely developed pods. Death of the whole tree may ensue from the damages.

Flies as pests may cause considerable damages in many cultures. The maggot of the Mediterranean fruit fly *(Ceratitis capitata Wied.)* destroys the tissue of citrus fruits and excretes ferment-like substances causing rapid rotting of the fruit tissue. Under the favourable climatic regions of the Mediterranean region up to 9 generations may develop within a single year. With developing international trade this pest is also being introduced to other countries where it is a dreaded quarantine pest. Circumspect control must include total destruction of infected fruits, soil disinfection (the larvae pupate in the soil) and cultural practices (mixed growing of different strains). Chemical control measures using chlorinated hydrocarbon insecticides and organophosphorus compounds also are advisable (fig. 30).

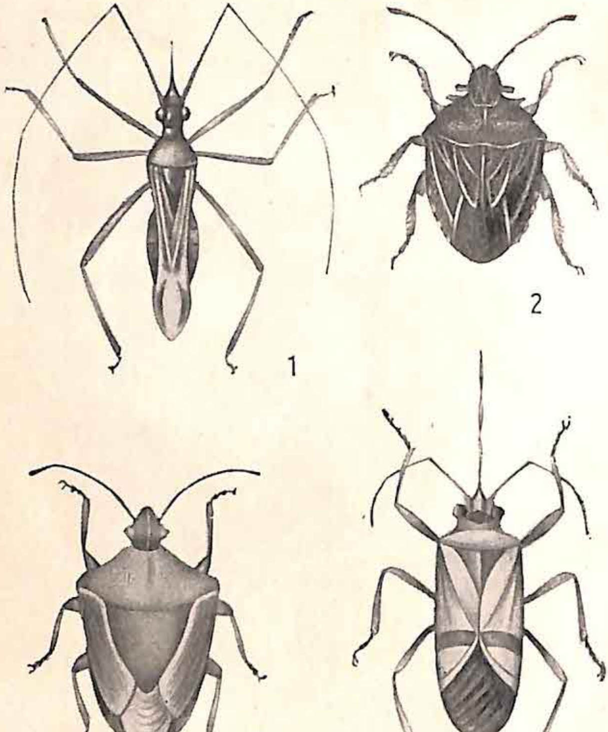


Fig. 28. Capsid bugs
1 helopeltis bug
2 black bug of paddy *(Scotinophora lurida Burm.)*
3 green rice bug *(Nezara viridula L.)*
4 red cotton bug *(Dysdercus nigro-fasciatus Stal.)*

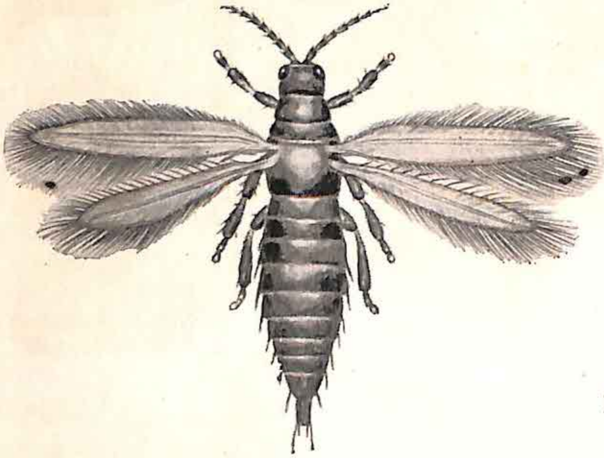


Fig. 29. Thrips

Colour plate I. Virus diseases

1 cocoa swollen-shoot disease 2 tobacco mosaic

Colour plate II. Bacterial diseases

1 of tomatoes *(Corynebacterium michiganense (Erw. F. Smith) Jensen)*
2 of cotton *(Xanthomonas malvacearum (E. F. Smith) Dowson)*

Larvae of flies live in various parts of plants (fruit, flower, root and stalk flies). The larvae of mangold flies *(Pegomyia hyoscyami Panz.)* bore galleries (mines) between the leaf under and upper side (leaf miners).

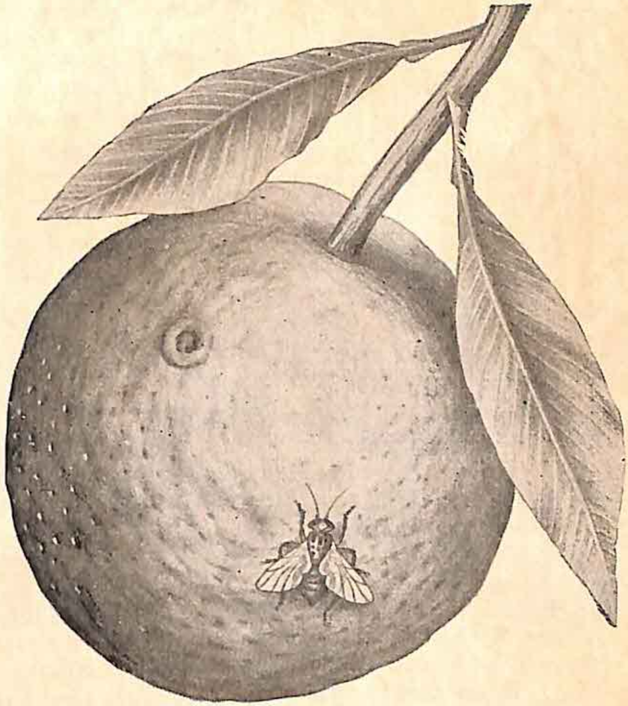


Fig. 30. Mediterranean fruit fly *(Ceratitis capitata Wied.)*

G. SNAILS AS PLANT PESTS

Characteristic of snails on green plant parts are slime tracks on plant surfaces and the pattern of damage caused by rasping feeding. Snails can be controlled either by collecting them by hand or by distribution of caustic fertilizers (lime) or chemical agents (molluscicides). A typical agent of the latter type is metaldehyde which can be worked into a bait with wheat bran (fig. 31).

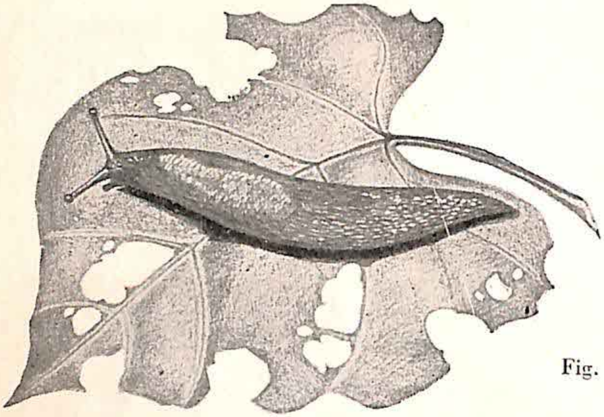


Fig. 31. Snails as plant pests

H. BIRDS AS PLANT PESTS

Many bird species, when occuring in masses, may cause considerable damage by feeding on germinating seeds, flower buds, ripening corn seeds and green plant parts. Control of such bird species is problematic because they also feed on injurious insects. Control measures are primarily of a mechanical nature, such as erection of traps, sealing of hiding and sleeping places with mud, removal of eggs from nests and nest detruction, use of scares and exhibition of dead birds.

Chemical agents have also been employed to combat the common sparrow *(Passer domesticus L.)* which lives in nearly all continents. At first blue-green wheat baits are used to attract the birds. When these have become used to the locality and have fed on the bait the control action begins with the distribution of blue-green wheat baits containing strychnine. Great caution and frequent controls must be exercised during such an action to avoid jeopardizing man and animals. Numerous types of crows are combated by distributing meat or chicken-egg baits poisoned with arsenic, strychnine or phosphorus. However, distribution of poisoned meat should be avoided, the danger to other animals being too great.

I. RODENTS AS PLANT PESTS

Rats and mice are dangerous both as pests in stored products and as carriers of many diseases (dysentery, cholera, tuberculosis). Occuring everywhere, they live predominantly in refuse heaps and rubbish but also in granaries, store rooms, cellars and stables. On the one hand they cause considerable damage by

devouring large quantities of food and on the other by polluting stored products and also by their high rate of reproduction. Owing to the agile movements of these animals and their hidden way of life control often is difficult. High percentage extermination is only possible by organized measures throughout whole districts. By distributing poison baits or fumigating closed rooms extermination is quite feasible (fig. 32).

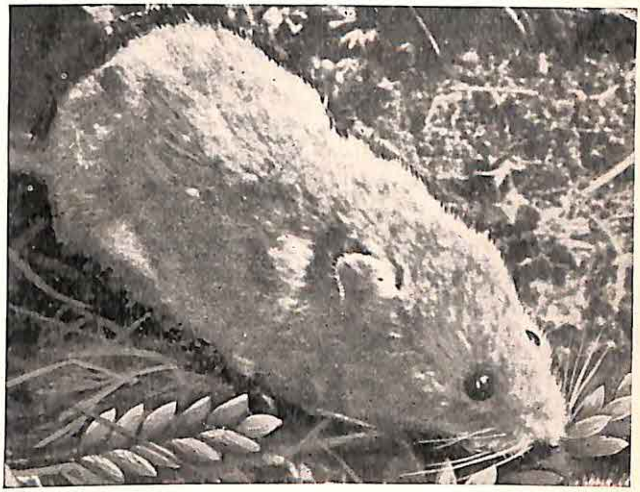


Fig. 32. Rodents as plant pests

V. THE ORIGIN OF DISEASE EPIDEMICS AND PEST CALAMITIES

A. DISEASE PREREQUISITES

Disease pathogens and susceptible plants are necessary prerequisites for disease outbreaks. Conjunction of both types of organism under given conditions of environment must be assured. The plants must possess a certain disposition to attack by disease pathogens. This disposition to illness depends upon the plant constitution and is governed to a large extent by environment factors. The degree of disposition reached at a certain instant which depends on plant build and viability is termed pre-disposition. A behaviour restricting disease pathogens in their development is termed resistance. It is governed by the total sum of constitutional properties which inhibit a parasite's effect despite its aggressiveness.

B. THE ORIGIN OF DISEASE PATHOGENS

(1) Transmission of disease pathogens

Disease pathogens or pests can be spread passively, by wind, water, man or animals or actively, by wandering or flying, for example.

(2) Infection

Disease pathogen and plant enter into correlation. The time between beginning germination of the pathogen (e.g. spores of fungi) and establishment of a close relationship between pathogen and host (plant) is defined as the time of infection.

(3) Incubation stage

After infection has taken place a certain period of time elapses before the first obvious disease symptoms appear (time of incubation). The times of infection and incubation are of great importance for predicting disease outbreaks and for selecting control measures. If the interdependence of infection and incubation with climatic conditions is known predictions of diseases can be made

(prognosis), warnings can be passed on to representatives of the control service (warning service) and control measures introduced, thus preventing further infections prophylactically.

C. DISEASE PROGRESS

Disease outbreaks are characterized by the appearance of first visible disease symptoms. The subsequent progress of diseases depends upon several factors. If a disease does not remain restricted to individual plants this leads to locally or periodically appearing mass infections, so-called epidemics. During the further progress of diseases and as a consequence thereof the plants exhibit effects which ultimately may lead to the death of individual plant parts or of entire plants.

D. MASS GRADATION, MASS MULTIPLICATION

The extent of damages after attack of plant cultures by insects depends to a lesser degree upon the state of the plants than on the numbers of these pests. Investigations of mass outbreaks are directed particularly at the elucidation of the underlying causes for the mass multiplication of serious pests at irregular time intervals. Mass increase of insects begins with a slight increase in numbers gradually reaching a climax of over-reproduction followed by abatement. This change in multiplying is termed gradation. Such mass outbreaks constitute calamities for plant cultures. Knowledge of the underlying factors of gradation is of great importance for practical plant protection measures. Such factors are: climate and weather conditions and the animate and inanimate environment of the insects. Inner factors and cultivation conditions of useful plants are of decisive significance, too.

VI. WAYS OF CONTROLLING DISEASE PATHOGENS AND PESTS

A. PREVENTIVE MEASURES

(1) Cultural measures

Many pests and diseases of cultivated plants can be controlled or prevented by expert application of plant cultivation measures alone.

Crop rotation

Regular crop rotation is a very efficient plant hygienic measure. Not only economic reasons but above all biological aspects are the deciding factors. Uninterrupted cultivation of a crop for long periods of time not only leads to a drop in harvest yields but also furthers the outbreak of diseases, weeds and pests.

When deciding on the sequence of crop rotation the mutual compatibility of cultivated plants must be taken into consideration. When working according to a long term plan of cultivation it must be considered whether certain pests or fungi have specialized on one cultivated plant only or whether they attack several cultures. Changing from foliage plants to cereals and truck crops and from annual to perennial plants always assures a good crop rotation.

Consideration of the demands of cultivated plants

Knowledge of the demands of a cultivated plant on soil, climate and location may also be regarded as a preventive measure. Creation of the best conditions for the cultivation and development of food plants must be aimed at. Only such crops should be grown which thrive well at the site of cultivation and thus secure high harvest yields.

If the soil is unsuited for crop growing then cultivated plants are in particular danger from pests and diseases during their development.

Soil cultivation

Intensive soil cultivation is very important. It should serve not only to preserve but also to maximally improve the chemical and physical state of the soil and thus to influence the water economy favourably. It is also important to know whether a certain food plant prefers acid or alkaline soil, otherwise

its development will be retarded. However, with expert fertilizing the desired soil reaction may be obtained. The following are optimal pH values: for cotton: 7—8, bananas: 4.5—8, citrus fruits: 5.5—6, coffee: 4.2—5.1, cocoa: 6, rice: 4.5—8, tea: 7 and sugar cane: 7.

Seeds and seedlings

Favourable environment conditions are not the only factors necessary to obtain healthy plants. They also include the quality of seeds and seedlings. Plants giving high yields can only be grown from healthy seeds and unimpaired cultures. The proper time of sowing or planting, the recommended depth of sowing, width of planting and measures of cultivation, they all must be observed. If possible, seeds should be treated with chemicals to destroy or prevent the development of adhering spores of fungi.

Fertilizing

The application of fertilizers, playing an important part in plant nutrition, is of decisive importance. When sufficient quantities of fertilizers have been applied and a harmonic ratio of nutrient substances obtains in the soil, plants will thrive, harvests will be good and food plants will overcome damages previously inflicted by pests and diseases better.

With most tropical and sub-tropical cultures the nutrient demands are being satisfied only partially. Often only insufficient quantities of stable manure are available. All organic refuses must, therefore, be composted carefully under all circumstances. Burning of organic substances is on no account justified. A regulated humus supply is one of the most urgent requirements if the soil is to remain productive. Humus material contributes significantly towards improving air, water and nutrient conditions in the soil. Lack of one or more nutrients leads to physiological disorders.

When nitrogen deficiency obtains oil palms develop a striking light green discolouration of the youngest leaves, sugar cane tillers inadequately, the leaf tips wither, growing stops prematurely and stems remain thin. Cotton plants exhibit stunted growth, their leaves showing chlorotic symptoms, capsules remain unripe and are cast off. An insufficient supply of nitrogen also furthers the spread of banana wilt.

Normal and balanced doses of nitrogen lead to strong and rapid growth and overdoses to soft, unstable spongy plant tissue which is particularly susceptible to attack by pests and diseases. Furthermore, ripening of plant organs is delayed. Doses of phosphoric acid and potassium compounds enhance the stability of plant tissues. This improves the resistivity to strong winds. Deficiency of phosphoric acid adversely affects efflorescence and the setting of fruit. Potassium deficiency retards longitudinal and diametric growth of oil palms and bananas. A good potassium supply is particularly important for citrus fruits. The peel remains thin and colour, juice content, taste, condition and keep quality are influenced favourably. With potassium deficiency soft, easily rotting fruits develop which drop prematurely and branch tips dry up.

The significance of lime as an indispensable nutrient and soil-improving means must not be overlooked. A deficiency of certain trace elements (boron, magnesium, zinc, manganese, molybdenum, copper, iron, cobalt, iodine etc.) leads to pronounced susceptibility to pests and diseases and to manifold chlorotic leaf discolourations.

(2) Plant quarantine

Disease pathogens and pests do not respect state borders. With international traffic quickening they are carried easily from country to country and from continent to continent. Among their ranks may be found the Japanese beetle *(Popillia japonica Newm.)*, the European corn borer *(Pyrausta nubilalis Hübn.)*, the Colorado beetle *(Leptinotarsa decemlineata Say.)*, the white tiger moth *(Hyphantria cunea Drurg.)*, the woolly louse *(Eriosoma lanigerum Hausm.)*, the vine louse *(Phylloxera vastatrix Planch.)*, the San José scale *(Quadraspidiotus perniciosus Comst.)*, the Mediterranean fruit fly *(Ceratitis capitata Wied.)*, nematodes and other seed- or plant-borne diseases. Owing to the danger of importing diseases and pests several countries have passed special quarantine regulations for the protection of cultivated and food plants which stipulate inspection of all plant imports with issue of health certificates or prohibit the import of certain plants and plant parts.

If quarantine pests are discovered the whole consignment is rejected and turned back to the country of origin or destroyed on the spot or used for other purposes.

In cases of low degree infection, when import has been permitted disinfection measures are ordered.

Inland transports of plants or seeds are also subject to quarantine regulations (internal quarantine). Infected seeds or seedlings must not be transported from infested areas. Such measures are of special importance in preventing the spread of nematodes. Quarantine regulations help to erect barriers for disease pathogens within countries. By isolating infested areas and adopting appropriate disinfection measures vulnerable cultures may be saved.

(3) Disinfection measures

Many disease pathogens and pests which adversely affect germination and growth of cultivated plants are found in the soil and on seeds. Seed-borne disease pathogens, in particular, spread diseases to hitherto uninfested areas of cultivation. Disinfection measures aim at destroying injurious organisms in the soil and on seeds, two types of disinfection being possible:

(a) Soil disinfection
(b) Seedling and seed disinfection

Soil disinfection

Soil disinfection is directed at disease pathogens and pests living in the soil. It should be carried out where there are appreciable concentrations of inju-

rious organisms. This is frequently the case in soils with permanent mono-cultures or faulty crop rotation.

The aim of soil disinfection is

to eliminate or control disease pathogens and pests with maximum success,

to injure beneficial organisms inhabiting the soil as little as possible and not to affect the physico-chemical state of the soil negatively.

The following types of soil disinfection measures may be mentioned:

Biological disinfection

Physical disinfection

Chemical disinfection

Biological disinfection measures

Destruction of disease pathogens and pests is effected by admixing organisms with the soil. Successful experiments have been carried out with micro-organisms but these measures have not yet been generally introduced in practice.

Physical disinfection measures

Physical measures can be: application of heat, electricity, supersonic waves, flooding and replacement of soil. The most important procedure of this type is soil steaming, heat being applied in the shape of steam. This procedure has the big advantage of not seriously affecting the physico-chemical properties of the soil if carried out expertly. The choice of possible variations of this procedure is governed by the fact whether the soil to be disinfected can be transported or not. When deciding upon the procedure to be adopted the nature of the pests in the soil must be taken into consideration, too, because the susceptibility of organisms to temperature differs. The most widely used procedure, applied chiefly in horticultural enterprises, is the steaming of agitated soil in steam barrels. The duration of soil steaming depends upon the degree of infestation by organisms and the nature of the soil (dry, wet, light, medium or heavy) and varies from 10 to 45 minutes. In practice, it is recommended to introduce hot steam into the soil to be disinfected for 10 to 20 minutes and to allow the soil temperature to rise up to 95 °C. After steaming, the soil must be allowed to rest for 2—3 weeks. Occasional turning is expedient.

Chemical disinfection

The feasibility of chemical soil disinfection depends upon the construction of certain implements and the use of chemical substances with low toxicity. Chemical agents which may be used are: compounds of potassium, mercury, copper, manganese, ammonia and arsenic, formaldehyde, cyanides, carbon disulfide, carbon tetrachloride, benzene and phenolic compounds, chloropicrine, mineral oils and other compounds. The agents act differently upon the organ-

isms to be controlled: carbon disulfide is employed to control animal organisms, formaldehyde is used for controlling fungi living in the soil and bacteria, and chloropicrin for soil fungi, bacteria, animal pests and nematodes. Depending upon their toxicity for beneficial organisms, their power of soil penetration or other harmful properties, chemical agents must be applied in different ways. Time of application and dosage must be laid down exactly. These agents are applied by spreading, pouring, drilling in together with the seeds and by injection into soil with special implements (soil injectors).

The choice of the application method is determined by the size of the area to be treated.

Seedling and seed disinfection

Control of fungal and bacterial disease pathogens on seeds or seedlings with chemical agents has found widespread application (see pages 72, 73, 127). Animal pests are controlled by immersion, watering or dusting of seeds or seedlings with chemical agents (insecticides).

B. ERADICATION MEASURES

(1) Mechanical eradication measures

To-day, as far as big conjoined areas of cultivation are concerned, mechanical control measures are of minor importance only. On small areas or in countries with a man-power surplus mechanical control measures are still customary.

Mechanical control measures are:

(a) Collecting or picking of egg masses, leaf-feeding caterpillars and beetles from food plants by hand to prevent further spreading of pests. Collected pests or eggs must be destroyed.

(b) Gathering of fruits dropping prematurely before harvest. Usually they are infected with diseases or pest-ridden and must be buried deep in the ground or burned.

(c) Removal or uprooting of entire plants or certain plant parts containing egg masses, stem borers, caterpillar colonies or webs or attacked by fungus or virus diseases. In many cases this procedure is still the most effective method to check fungal diseases highly resistant to chemical agents.

(d) Separation of pests such as the rice weevil *(Sitophilus orezay L.)*, the common bean beetle *(Acanthoscelides obsoletus Say.)* and the Khapra beetle *(Trogoderma granarium Ev.)* by picking out from seeds or by sifting stored products.

(e) Brushing and scraping of fruit trees with wire brushes and scrapers to remove bark scales, mosses, lichen and simultaneously to destroy pests which have found hiding or breeding places there. The scrapings must

not be left lying on the ground. They are collected on tarpaulins, sacks or thick paper and burned afterwards.

(f) Knocking-off leaf-feeding beetles and sucking bugs over collecting funnels or clothes placed underneath.

(g) Erection of light traps to attract and destroy moths such as the rice stem borer. Nowadays sources of light are employed by the warning service and used to make forecasts. Light traps serve to obtain a rough survey of the occurrence of certain pests so that practical control measures can be recommended.

(h) Erection of artificial hiding places with boards, tubes, bricks, corrugated cardboard and other materials. Pests hiding in such places are collected and destroyed or dusted with insecticides.

(i) Trapping of pests with grease bands, attracting liquids in bottles and other vessels or distribution of food baits connected with traps or similar devices.

(k) Cultivation of so-called catch crops which are preferentially attacked by the pest to be destroyed. They are sowed out or planted ahead of cultivated plants so that pests collect, oviposit or feed there first. When pests have collected or oviposited there in masses the catch crops are torn up or ploughed under.

(l) Digging of trap ditches around cultivated areas to keep immigrating or leaf-feeding pests away from food plants. They must have a minimum depth of 25 cm and must be broader at the base than at the top. The ditch walls which serve to prevent pest migration must be overhanging. At the base of the ditch, roughly 10—15 m apart, 25 cm deep pits should be dug in which pests collect in large numbers. The pests trapped in the pits and ditches must be collected daily and destroyed.

(m) Erection of enclosures such as wood or wire fences, bamboo or cactus hedges; protection of individual trees from browsing by wild or domestic animals with wire mesh and wooden boxes.

(n) Setting up of scarecrows to keep away animals and birds.

(o) Ignition of crackers to prevent bird swarm invasions.

(p) Flooding or burning of stubbles.

(2) Biological eradication measures

Next to the destruction of pathogens by chemical agents attention must be paid to biological control. The latter aims at the reduction of harmful animals or plants by means of natural foes or beneficial organisms to such an extent, that equilibrium is restored again in nature. Biological control includes, in principle, all possible ways of using organisms against organisms.

However, the concepts of "beneficial organism" and "pest" are unknown in free nature. Such organisms termed "beneficial" by man destroy both pests and beneficial organisms indiscriminately. It also proves impossible to multiply foes of injurious insects at random because there must be sufficient food viz. pests, for them. If this is not the case the population of beneficial organisms will diminish. They can only appear again in greater numbers upon mass multiplication of a pest.

In biological pest control several routes may be pursued which often prove successful only when mutually supplementing each other.

Such routes are:

Re-introduction of native useful organisms grown rare owing to dislocation of the natural equilibrium such as bats, shrews, hedgehogs, toads or insects like chalcidoidae, ichneumon flies, robber and hover flies, cantharids, lady beetles, cone-nodes bugs, forest ants, chrysopidae, predaceous mites and others. Numerous insects parasit on eggs, caterpillars and pupae. Those insects parasiting numerous species of stem borer caterpillars in maize, rice and sugar cane are particularly useful.

Importation of superparasites. This means introduction of such animals not native to a certain pest-ridden country which live on that same pest in their native country. The lady beetle *Novius cardinalis Muls.* is an excellent example of this procedure. In the citrus fruit plantations of California (USA) a scale suddenly began to spread to such an extent that economic collapse threatened. Investigations were conducted to find out the origin of this dangerous pest and it was found to be a native of Australia. There this scale was unknown as a pest and occured only in small numbers. This was due to the beetle *Novius cardinalis* which feeds on the scale, thus preventing its mass multiplication and serious damages. The useful beetle was brought to California and it proved possible to decimate the masses of scales living on citrus plants to such an extent that the species no longer constitutes a danger to citrus fruits.

Another example is a species of the *Chalcididae* family *(Aphelinus mali Hald.)*, the natural foe of the woolly louse *(Eriosoma lanigerum Hausm.)*. This beneficial insect, a native of North America, was imported to Europe. It was hoped that its naturalization would be successful, thus assuring destruction of woolly lice. In Italy and Southern France these hopes were fulfilled but not in the Northern European countries. Though naturalization was successful in many places there, woolly lice were not significantly checked so that the use of chemical agents still is necessary.

The chalcididae species *Trichogramma minutum Riley* is raised artificially and released to control sugar cane borers. It parasites the eggs.

Experiments have been carried out with bacteria, fungi – e.g. *Beauveria densa* – and virus species, but up to now these plans could not be implemented in practice, as yet.

Bird protection, too, is a part of biological pest control. The point is to maintain the numbers of entomophagous small birds. This is possible by sparing them and by creating suitable places for nesting.

Land cultivation by man has deprived many useful bird species of their conditions of life. However, people are inclined to overrate the importance of insect-feeding birds. Instances of prevention of mass pest multiplication by strong bird populations have become known only in forestry so far. These few cases led to the conclusion that pest control is possible solely with intensive bird protection. In monocultures, with their animal population of a few species tending to mass multiplication, neither birds nor other beneficial organisms are in a position to decimate pests to such an extent that chemical control measures become superfluous.

On the whole, when compared with chemical control, biological control is of minor significance. The presence of predaceous insects and mites, insect-feeding birds and animals in an area cultivated with food plants is, of course, welcome, but its significance should not be overrated. The natural helpers do not differentiate between pests and beneficial organisms and their reproduction usually is slower than that of the pests. In addition, numerous pests and most fungus diseases have no natural foes.

(3) Chemical eradication measures

Preventive plant hygiene measures and agrotechnical practices do not suffice to keep the numbers of vegetable and animal pests down at such a level that over-reproduction or losses between sowing and harvesting or consumption are averted. With the development of chemical control agents, which are being improved all the time with regard to their effectiveness and modes of application, mankind is in a position to stand its ground in its struggle against pests and diseases. Chemical control agents more and more supersede century-old mechanical control measures or have replaced them altogether.

In present-day plant cultivation no satisfactory harvest yields can be obtained with most plant cultures without employing chemical plant protection agents. In pest calamities, in particular, the application of chemical agents is the only way to protect or to secure the survival of plant cultures. It can be said that the use of chemical plant protection agents has led to the broadening of the food basis for the steadily growing mankind and thus has helped to secure its life. It cannot be stressed enough that to-day there would not be enough food for the population of our planet if serious harvest losses are not prevented by means of chemical plant protection agents. However, it must also be said, that despite this technical progress, plant protection is not yet being exploited optimally with respect to crop yields and crop preservation. There still is a sufficient reserve left to increase food supplies for mankind if far more is done in the way of plant protection than to-day.

Numerous pesticides serve to stave off or to destroy pests and disease pathogens of cultivated plants. However, it must be borne in mind that plant protection cannot offer a panacea neither to-day nor in future because the origins of plant diseases are far too manifold and pest insects differ in their reaction to active agents contained in plant protection products. The selection of con-

trol agents is determined by the nature of the disease pathogen or the exterior, feeding habit and way of life of the pests. Correct selection of agents is, therefore, a basic condition for successful control.

If the above is not observed set-backs will follow. Sulfur-containing plant protection agents, for example, are frequently used for the control of *Peronospora*, though this disease can only be successfully controlled with copper-containing or organic fungicides.

A further cause for set-backs when applying plant protection measures is wrong timing, that is application of plant protection agents at a time when plant diseases or pests are not yet to be expected or when the damage has already been done. In principle, all plant protection measures should be initiated upon first signs of the causative organism, taking care that no damage has as yet been incurred at the time of execution.

The temperature reigning during a control action is of no little importance. At high temperatures sulfur-containing agents, for instance, not only prove ineffective but may even cause leaf scalding. The effectiveness of insecticides containing organic phosphorus compounds as active agents drops with falling temperatures.

Set-backs may be occasioned by the mode of application of pesticides. Unsuitable implements or machines or disregard of the recommended concentrations may be the underlying causes. It would also be a big mistake to assume that larger quantities help more and that there are no biological effects when using lower concentrations than recommended. Excessive concentrations not only may lead to scalding of plant organs, in the case of pronounced stomach poisons even a repellant effect on pests may result. Every practical worker should bear in mind during all control measures that no set-backs occur when the proper agent is applied at the proper time in the proper manner.

VII. CHEMICAL CONTROL AGENTS

A. CLASSIFICATION OF CHEMICAL CONTROL AGENTS ACCORDING TO THE RANGE OF ACTION

Chemical control agents may be classified according to their range of action as follows:

Fungicides

Fungicides are agents which destroy fungal disease pathogens. Their action may be prophylactic, germination of fungus spores on treated plants and penetration of fungal pathogens being prevented. They are not able to kill fungi which have already succeeded in penetrating. There are, however, some fungicidal agents with a curative action which destroy fungi that have already penetrated into the plant tissue. Many fungicides have a specific action on certain fungi only.

Insecticides

This group includes all control agents which kill diverse kinds of adult insects and their immature stages. No single insecticide is effective against all types of insects. They all exhibit a more or less restricted effectiveness.

Acaricides

Agents included in this group kill spider mites and other mites.

Nematicides

They are defined as chemical control agents acting against nematodes in the soil, on roots, in stems and leaves.

Molluscicides

These agents, distributed by scattering or as baits, are effective against snails.

Rodenticides

Agents of this type kill rodents such as rats, ground-, field-, house and pine mice. They are distributed by scattering or added to water or worked into baits.

Herbicides

Herbicides are chemical agents which kill seed and root weeds. They may be selective or non-selective in their action.

B. CLASSIFICATION OF CHEMICAL CONTROL AGENTS ACCORDING TO THE MODE OF APPLICATION

In accordance with their application chemical control agents are formulated in various ways. We distinguish:

Dusts
Sprays
Aerosols
Special agents

Dusts

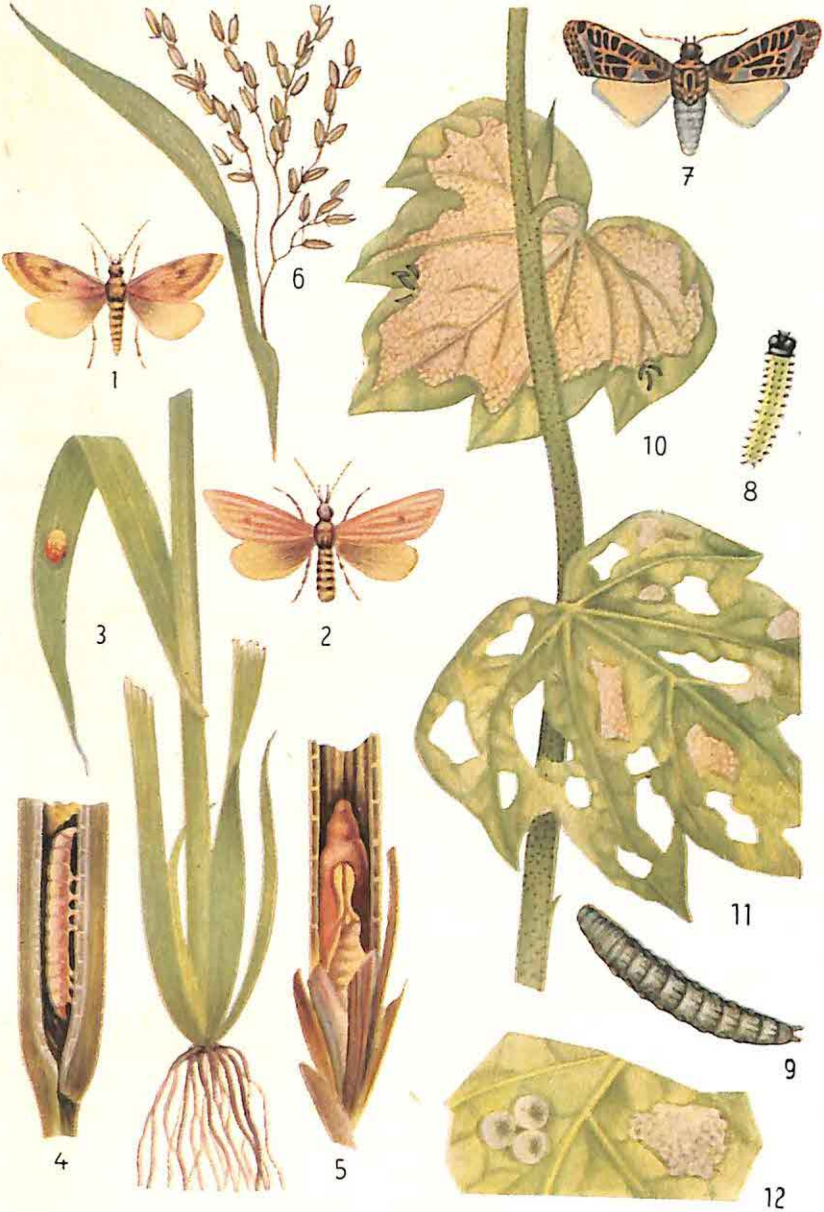
Dusts are ready-for-use control agents. The active agent is compounded with dry, ground mineral carriers. It is important to obtain the optimum degree of fineness during grinding. Particle sizes range from 5 μ to 50 μ. If dust particles are too coarse they run off the plants, if, on the other hand, they are too fine they are not deposited quickly enough on the plants and are carried away by air currents. To prevent the components from separating during application intimate bonding of the active agents with the individual carrier particles is a necessary prerequisite. Furthermore, the active agents must be evenly distributed on the carrier. In addition dusts must possess good dusting and adhesive properties. The particles must not agglomerate. Addition of an adhesive which coats the individual dust particles, thus keeping them separated, considerably improves dusting properties and also the adhesivity on plants and even on smooth leaves.

Thus good particle separation engenders good dusting properties. Such dusts possess a mobile consistency, flowing easily in dusting apparatus without bridging or stopping up the dust feed pipes. Despite good adhesivity dust deposits possess low stability to wind or rain. A certain stability to rain is obtained by dusting wet plants or prior to dew formation. The category of dusts also includes powders, dredges and dry seed disinfectants. They are all dry powdery compositions with a limited range of application. They may serve to protect seeds against soil pests or fungal diseases or are applied against pests in stored products or used as sprout inhibitors.

Dredges, which belong to this category, are dry, coarse, particulate compositions without dusting properties. Particle size exceeds 100 μ. They are applied with special implements or by hand and used primarily against soil pests such as white grubs, cutworms and wire worms. Frequently they are incorporated into the soil to protect seedlings against leaf miners.

Colour plate III.

1 coffee rust *(Hemileia vastatrix Berk. et Br.)*
2 powdery mildew of vines *(Oidium Tuckeri Berk.)*



Colour plate IV. Rice stem borer (1—6)

1 male moth · 2 female moth · 3 egg mass on rice leaf · 4 caterpillar in stem · 5 pupa in stem · 6 empty panicle · Cotton leaf worm (7—12) · 7 moth · 8 caterpillar (after hatching) · 9 caterpillar (prior to pupation · 10 injuries caused by young caterpillars · 11 injuries caused by older caterpillars · 12 egg mass on leaf

Sprays

With the exception of sprays and fogs for aircraft application sprays, unlike dusts, are not delivered ready-for-use. To bring them into a form ready for spraying or atomizing they must first be diluted with water by the applicant. Sprays may be subdivided into:

Liquid sprays

Wettable powders

Liquid sprays

The following types may be distinguished:

Physical solutions

In physical solutions the spray liquid is absolutely clear and homogeneous. The dissolved agents cannot be seen under a microscope.

Colloidal solutions

These constitute an intermediate stage between physical solutions and suspensions. The active agent particles also cannot be discerned under a microscope but rays of light are refracted. Highly diluted colloidal solutions resemble physical solutions.

Emulsions

In emulsion sprays the active agent is dissolved in an organic solvent, rendered miscible with water by means of emulgators. Spray liquids, ready for application, are opaque, usually milky liquids wherein the active agent is dissolved in finely dispersed solvent droplets.

Wettable powders

On mixing wettable powders with water – after first stirring them with a little water to obtain a free flowing paste without clots – a spray liquid containing the active agent as a fine disperse suspension is obtained. Spray liquids composed of a solid powdery substance and water are termed suspensions. To improve adhesion on such plants which prove difficult to wet, adhesives may be added to the made-up spray liquid.

Aerosols

These are ready-for-use preparations containing the active agent dissolved in an organic solvent. They are clear liquids. Upon application the solvents evaporate rapidly leaving tiny, invisible highly concentrated particles of active agent distributed in the air.

Special agents

Special agents have been formulated for the control of numerous pathogens and are applied by special procedures.

Fumigants

These preparations are applied against stored-product pests in silos, mills, ships and sacks and against hot house pests and house vermin and used for disinfecting plants, fruit and vegetables. They all are highly toxic compositions. Their application is governed by special legal regulations.
The following are used in practice:

Hydrogen cyanide, phosphine-liberating preparations and methyl bromide. The preparations consist of rapidly evaporating liquids and gases which are discharged from containers or of agents adsorbed to carriers and liberated as gases upon contact with the atmosphere. Some agents vaporize only after application of heat. Various types of fumigating devices have been installed in big granaries.

Smoke-fumigants

These are applied against house vermin, stored-product pests, in hot houses and in the open. The preparations are used in the form of tablets, strips and cartridges. On heating or ignition they evolve smoke containing active agents as gases or very fine particles. Smoke cartridges are used in the open against small rodent pests. They are inserted into the holes and, after ignition, produce toxic fumes. Special smoking appliances have been developed; when these get choked up there is danger of explosions.

Baits

For the control of insects, rats, pine mice, mice, birds, slugs etc. food substances are impregnated, wetted, powdered or mixed with a poison. The prepared poison baits or bits are distributed or broadcast or inserted into holes and burrows. They may have to be prepared at home but commercial preparations also are available. Thallium sulfate, zinc phosphide, red squill and coumarine preparations are applied against rodents, strychnine against sparrows and metaldehyde against slugs.

Incrustation agents

During the last few years incrustation of seeds with various agents has become an important preventive measure. This method is simple, successful and economic. Usually special agents are applied to protect seeds against the larvae of various vegetable flies, flea beetles and snout beetles. However, the protective effect does not extend over the whole vegetation period.

Seeds are stirred with a certain amount of water (50—200 c.c./kg seed) by means of a piece of wood or a spatula and wetted uniformly. A drum may also be used for the purpose. With continued stirring a certain quantity of incrustation agent (50—250 g/kg seed) is added gradually and mixing continued till the seed corn is uniformly covered. The seeds are then dried in the air and must be drilled out immediately. When incrustating it is important to adhere exactly to the specified quantities of water and preparation. To improve adhesion properties starch solutions may be added, but in most cases this is not necessary.

Paints

These more or less viscous preparations are still being used and applied specially against a small number of pests. They include the so-called insect pastes which are applied to water-impervious paper collars or trap boards to trap caterpillars, butterflies and weevils. The paste must be of such a nature that it retains its stickiness for as long as possible.

Occasionally agents are applied with brushes e.g. when woolly aphid colonies on twigs and shoots are daubed directly with pesticide compositions. This rather circumstantial procedure is of significance in cases of weak infection of single plants only.

Repellents

These agents, non-poisonous preparations of evil taste or smell, are used to keep off large and small game and birds from plantations, drilled seeds or seedlings.

Wound dressings

These are tree waxes, tree resins and tree tars, used to seal wounds or graftings of fruit trees to prevent infection by fungi.

Preparations to prevent deficiency diseases

These preparations contain trace elements and are applied to the soil or distributed by spraying when nutritive disorders and diseases of cultivated plants develop. They are chiefly composed of boron-, copper- and manganese-containing fertilizers, borax, copper and manganese sulfate, sodium and ammonium molybdate and metal chelates. For the treatment of iron deficiency symptoms on citrus trees iron chelates proved particularly successful. Iron deficiency on citrus trees manifests itself by shrinkage and yellowing of the leaves with subsequent decay of the branches.

Growth regulators

These preparations contain minute traces of synthetic growth promoters and thus influence certain processes within the plant in ways useful to man.

They include, for example, preparations to improve rooting of cuttings. Cuttings or flower bulbs are dipped into the dust. Root growth is strongly stimulated thereby and begins considerably earlier. There also exist preparations which regulate the setting of fruit on fruit trees, preventing premature fruit drop or facilitating early ripening.

C. COMPOSITION OF CHEMICAL CONTROL AGENTS

Only very few control agents contain one substance only. They nearly all contain several compounds which only in their totality develop the full effect. Chemical control agents contain:

Active agents
Additives

Active agents

The active agent is the most important ingredient. As a rule it alone acts on diseases or pests, hence its name. Control agents consisting of pure active agents only, are rare. Total herbicides containing sodium or potassium chlorate, for example, some 2,4-D- and MCPA-preparations and fumigants are composed of pure active agents. High concentration preparations may contain up to 85 % of active agent. We distinguish between inorganic, natural organic and synthetic organic active agents.

Additives

Additives serve to confer the desired properties upon control agents and secure or even enhance their effectiveness.
Such additives may be:

Solid carriers

They possess a powdery consistency and serve as adsorbants for liquid active agents. The following are used to prepare dusts and wettable powders: ground slate and other ground minerals, kaolin, lime, chalk, kieselguhr, silica, talcum, grain flours etc.

Solvents

They serve to dissolve active agents which, as a rule, possess low solubility. They are chiefly organic hydrocarbons derived from oil or coal, such as diesel oil, mineral oil, spindle oil, chlorobenzene, petrol fractions or alcohols, tetraline, carbon tetrachloride, trichloroethylene, butyl acetate, ethyl acetate, ethyl butyl alcohol, methylene dichloride, chloroform etc. Some solvents themselves possess insecticidal properties.

Solvents must have a high solubility factor, must not possess harmful properties and must not be inflammable. They must not undergo undesirable reactions with the active agent to be dissolved therein or decompose or change in any way during the process of solution.

Emulsifiers

These additives, which are composed of substances with widely differing chemical properties such as soaps, sulfonated fatty acid esters, aralkyl sulfonic acids and reaction products of amines with fatty acids, effect fine dispersion of one liquid in another immiscible one, thus forming emulsions.

Wetting agents

Many plants possess such highly water repelling surfaces that spray liquids immediately collect to form droplets of which the greater part runs off. The cuticle of many insects possesses similar properties. Spider mites often live

under dense webs which normal sprays are unable to penetrate. The pest itself is not contacted by the spray liquid and the active agent. This difficulty is overcome by the addition of wetting agents, thus securing uniform distribution of the spray liquid on plants, webs and pests difficult to wet. Besides possessing good wetting properties they must be absolutely compatible with plants. They must not decrease the stability to rain of the spray film; this is particularly important in the case of fungicides. Most of the emulsifiers in use already come up to these demands.

Adhesives (stickers)

These are additives which improve the stability to rain of sprays and the adhesive properties of dusts. Such additives are gelatine, casein, glues, sugar, starch, resins, pectines, salts of fatty acids, mineral, fish and vegetable oils.

Dyes

They serve as warning agents for poisonous preparations. Certain poisons must be dyed with a certain warning colour, e.g. green, blue, violet or red.

Odorants

They are additives serving as attractants or repellents.

D. MODE OF ACTION OF CHEMICAL CONTROL AGENTS

Depending upon their action we differentiate between:

Stomach poisons

Stomach poisons may be applied only against such pests, which imbibe them together with their food. In the stomach or intestinal tract of the pest the poison then takes effect.

Stomach poisons may, therefore, be used to control leaf-feeding beetles, larvae of beetles, butterfly caterpillars and larvae of saw flies and rodents.

Contact poisons

The pests must contact these poisons. The actual poison effect is that of a nerve poison. As soon as insects or their immature stages walk over the poison film the poison penetrates into the insect body by way of the sensual organs or the soft synovial membrane and attacks and progresses within the nervous system. Typical symptoms of paralysis ensue which, in the end, lead to death. The time elapsing till the onset of the poison effects differs.

Respiratory poisons

These are substances taking effect after being introduced into the body as a gas or a gas-producing agent by way of the respiratory system, the lungs or the trachea.

Corrosive poisons

These poisons take effect by damaging the exterior protective covering of pests or plants and penetrating into the interior, thereby causing destruction of tissues and organs and subsequent exitus.

Systemic poisons

Various organic poisons penetrate into plant tissues through the roots or leaves and are distributed to all parts of the plant by the transpiration stream and partly by the assimilation stream without injuring the plant. These poisons are selective in their action. They kill sucking and leaf-mining insects and spider mites only. Only a few are effective against non-sucking insects and diptera.

Herbicides based on growth promoters may, in a certain sense, also be considered to be systemic poisons.

These synthetic plant growth regulators, which in their action and constitution resemble the phyto-hormones produced by plants, interfere with internal vital processes. They stimulate excessive cell growth in plants. As a consequence the plants exhaust themselves and die gradually. This effect is chiefly restricted to dicotyledons.

The above-mentioned poisons may either have a rapid initial effect so that the causative organisms are killed immediately after application of the control agent or a pronounced residual effect. Residual effect poisons remain effective for long periods of time, with the poison effect gradually abating owing to exterior factors such as rain, sun, wind and dew. Such poisons are able to kill insects hatching from eggs or migrating into the treated area at a later date.

The properties of the various agents can be supplemented by combining control agents with differing modes of poison action.

E. ACTIVE INGREDIENTS OF CHEMICAL CONTROL AGENTS

(1) Fungicides

Copper

The fungicidal properties of copper compounds are utilized in numerous compositions in nearly all tropical cultures. The old traditional Bordeaux- and copper sulfate-lime spray liquids have been replaced by commercial copper formulations permitting easier preparation of spray liquids and affecting growth of treated plants less.

Present-day copper preparations are characterized by extremely small particle size, high suspension ratio and extremely high stability to rain. They thus come up to all the qualities of the old Bordeaux mixture which was unsurpassed in its stability to rain. The most important copper compounds are

copper oxychloride and cuprous oxide. Copper hydroxide also is employed. Commercial copper-containing fungicides are available as sprays, dusts and combined preparations (with sulfur or insecticides). The copper content ranges from 15—17%. Copper preparations also are non-toxic to bees, so that spray treatments can be carried out during the flowering period when bees are in the field. Blossom sprays, however, should be avoided, because copper compounds may affect the fructification processes adversely.

Copper agents are still unsurpassed in their effect on downy mildew fungi and leaf spot diseases. They may be applied with success to control Colletotrichum blight of coffee *(Colletotrichum coffeanum Noack)*, thread blight of coffee *(Corticium koleroga (Ckl.) v. Hoehnel)*, coffee leaf spot *(Omphalia flavida Maublet-Rangel)*, coffee leaf disease *(Hemileia vastatrix Berk. et Br.)*, brown leaf spot *(Cercospora coffeicola Berk. et Ckl.)*, rice leaf spot *(Cercospora oryzae Miyake)*, tea blister blight *(Exobasidium vexans Massee)*, brown pod disease of cocoa *(Phytophthora palmivora Butler)*, yellow spot disease of sugar cane *(Cercospora koepkei Krüger)* and others.

Owing to their growth-inhibiting effect, the danger of scalding and fruit russeting in wet weather copper fungicides are being used less and less in fruit-growing.

Treatment with copper-containing fungicides must be prophylactic. This means, that there must be a protective layer on the plant parts when an infection threatens, to kill germinating fungus spores before they penetrate into the plant tissue. Once the fungi have begun to spread within the plant they cannot be combated with copper preparations any longer.

Sulfur

The fungicidal effectiveness of sulfur is restricted to mildew fungi. It is the only agent in question for this purpose. In addition, sulfur-containing fungicides may be used prophylactically to control *Fusicladium* and peach leaf curl. Sulfur preparations also inhibit the spread of red spiders.

The well-known lime-sulfur spray mixture, a standardized preparation, with a polysulfide-sulfur content of 15—18 g per 100 c.c. is little used nowadays. Owing to its strong phytotoxicity and low stability it has been replaced by colloidal sulfur and sulfur pastes. These contain elemental sulfur in fine dispersion suitable for spraying. They dissolve in water without clotting, forming colloidal sulfur spray liquids. There are yet other types of very finely ground sulfur dusts which, however, unlike colloidal sulfur, still leave large leaf areas uncoated. They are not fine enough to distribute uniformly over leaf surfaces.

To avoid severe burning sulfur preparations must not be applied during great heat and in strong sunshine, but since the development of fungal diseases is also checked by hot weather, spray treatments can be dispensed with, as a rule. Avoid spraying when temperatures exceed 30 °C. in the shade.

All sulfur preparations are non-toxic to bees so that spray treatment may be carried out during the flowering period when bees are not in the field.

Mercury

Mercury-containing fungicides are chiefly used as seed protectants. The active ingredients usually are highly toxic organic mercury compounds. They serve to control seed-borne disease-causing fungi such as rotten neck of rice *(Piricularia oryzae Bri. et Cav.)*, bacterial blight of cotton *(Xanthomonas malvacearum (E. F. Smith) Dowson)*, cotton anthracnose *(Glomerella gossypii Edg.)*, damping-off *(Rhizoctonia sp.)*, rice brown spot disease *(Helminthosporium oryzae Breda de Haan)*, black smut of rice *(Neovossia horrida (Tak.) Padw. et Azm.)*. They act prophylactically. However, not every type of seed can be treated. Certain vegetable and ornamental flower seeds are too susceptible. Mercury seed protectants are applied as slurries and dusts. Treatment is carried out in special seed treaters. With all these agents avoid using more than the specified amounts or germination may be affected. Mercury fungicides may also be used for soil disinfection purposes. To protect seeds not only against fungus diseases but also against soil pests, seed disinfectants have been combined with insecticidal agents. Seeds treated with mercury disinfectants may be stored but seeds treated with combined agents must be sown out immediately.

In fruit-growing, too, sprays containing organic mercury compounds are used both prophylactically and as a cure before and during blossoming to control *Fusicladium*. This is an example of a fungicide killing fungi within the leaf but the infection must not be more than 3—4 days old. When carrying out treatment it must also be borne in mind that several kinds of fruit are susceptible to mercury. Because of the danger of poisoning application in vegetable cultures and berry plantations is not feasible.

Organic fungicides

To-day so-called organic fungicides, containing neither copper nor sulfur, are being used to an ever increasing extent. Their name is not quite exact, since some of them contain organically bonded metals e.g. zinc, iron or manganese. It is, therefore, more exact to speak of copper-free fungicides.

The introduction of these modern fungicides was a great step forward in the control of fungal plant diseases. With copper and sulfur fungicides the main emphasis had to be placed on 100% extermination of harmful fungi. The side-effects on plants which, depending upon weather conditions, were more or less severe injuries of the host plant, had to be put up with. By using organic fungicides this shock effect can be avoided.

The active ingredients are tolerated by plants without ill-effects. They are non-toxic to man and domestic animals and, in general, non-poisonous to bees.

The organic fungicides may be classified into the following groups:

Thiocarbamates

These include:

Zineb	(zinc ethylene-bis-dithiocarbamate)
Maneb	(manganese ethylene-bis-dithiocarbamate)

Ferbam (ferric dimethyldithiocarbamate)

Ziram (zinc dimethyldithiocarbamate)

Thiocarbamates are used to control the following fungal diseases:

Brown eye spot of coffee *(Cercospora coffeicola Berk. et Ckl.)*, blue mould of tobacco *(Peronospora tabacina Adam)*, downy mildew of grapes *(Plasmopara viticola Berk. et Cort.)*, *Fusicladium sp.*, *Phytophthora sp.*, *Alternaria sp.*, red fire disease of grapes *(Pseudopeziza tracheiphila Müll.-Th.)*.

All thiocarbamates are ineffective against powdery mildew fungi. The manganese atom in Maneb simultaneously acts as a growth-promoting trace element.

Thiurams

These compounds are not metal salts but disulfides. Most experiences with this group have been collected with TMTD (*t*etra *m*ethyl *t*hiuram *d*isulfide). It is the only representative of this group worth mentioning. With low temperatures this agent does not quite come up to the thiocarbamates. However, it has a favourable effect upon the colour of fruits. Greater significance attaches to this fungicidal agent as a seed disinfectant for all types of seed. It may be used to treat very sensitive vegetable and flower seeds. TMTD-formulations do not affect germination adversely and even promote seed germination considerably. In soil drenches they may also serve to control seedling diseases.

The following diseases can be controlled with thiurams: Brown eye spot of coffee *(Cercospora coffeicola Berk. et Ckl.)*, leaf spot disease of coffee *(Colletotrichum coffeanum Noack)*, leaf spot disease of rice *(Cercospora oryzae Miyake)*, *Botrytis sp.*, *Fusicladium sp.* and others.

Chloronitrobenzenes

These agents are applied as dredges and sprays to control fungal pathogens attacking plants from the soil. They are able to kill pathogenic fungi in the immediate surroundings of the seeds.

The following diseases can be controlled:

Seedling diseases *(Pythium sp., Phoma sp.)*,
onion smut *(Tuburcinia cepulae (Frost) Liro)*,
brown spot disease of tomatoes *(Cladosporium fulvum Cooke)* and others.

Captan

This fungicidal agent is characterized by its very good plant compatibility and its wide range of action. Its stimulating effect upon plants and the formation of fruits with high finish are remarkable. In addition, Captan may be used as a dry seed disinfectant for sensitive seeds. It prevents seedling diseases and promotes seed germination. Lettuce seeds are the only vegetable seeds susceptible to Captan. Shortly after sowing or setting, seed raising boxes and

seed beds may be sprayed with Captan solution as a protection against damping off. In the dry state it can be worked into the soil.

The following fungal diseases can be controlled with the agent:

Leaf spot disease *(Septoria sp.)*,
late blight *(Phytophthora infestans de Bary)*,
leaf curl disease of peaches *(Taphrina deformans Berk.)*,
shot hole *(Clasterosporium carpophilum (Lév.) Aderh.)*,
Botrytis sp., *Peronospora sp.*, *Fusicladium sp.*, seedling diseases such as *Pythium sp.* and *Phoma sp.* and others.

Karathane

This fungicidal agent has a specific effect on powdery mildew fungi and, in addition, exerts an inhibitive effect on the development of spider mites.

Karathane is a prophylactic agent but may act as a curative if treatment is carried out immediately after infection has occured. Being more plant tolerant than sulfur it can be used in nearly all cultures, esp. for mildew control in ornamental plant cultivations. The low concentrations used in treating ornamentals avoid spray spot formation. Unlike sulfur preparations, Karathane is also effective at low temperatures (5 °C). However, care must be exercised at temperatures above 30 °C. It is particularly suited for sulfur-sensitive fruits.

Mineral oils

Certain oil fractions obtained by distillation and rendered emulsifiable by additives yield stable white emulsions when diluted with water. The action of these mineral oils is physical in nature, the pest being enveloped by an oil film which prevents respiration. Pure mineral oils act essentially on woolly aphids only. Mineral oils are used as summer oils for the control of scales and mealy bugs on evergreen sclerophyllous cultivated plants such as citrus, figs, palms and olives and for controlling the San José scale *(Quadraspidiotus perniciosus Comst.)* on fruit trees. The range and intensity of action may be increased by addition of insecticides. Undiluted mineral oils are also used as herbicides. During the last few years they have also been applied as fungicides. Their effectiveness can be enhanced by addition of organic fungicides. Mineral oils have been applied with success in banana cultures to control banana leaf spot.

(2) Insecticides

Chlorinated hydrocarbons

DDT

DDT stands for *d*ichloro*d*iphenyl*t*richlorethane. This agent is a contact and stomach poison. It takes effect upon direct contact with the cuticle of insects by penetrating the insect body, chiefly by way of the soft synovial membranes and the numerous sensory cilia but also at other spots and there attacking and

progressing within the nervous system. Convulsions and paralysis, which finally lead to death, follow. DDT also is an effective stomach poison when getting into the intestinal tract together with food. There it gives rise to the same symptoms of poisoning as described above.

DDT exhibits only a very small initial effect, success of control treatment becoming apparent only after several days. This is due to its very low vapour pressure. It possesses a strong residual action lasting for several weeks instead. This protracted residual effect is particularly useful when pests appear and oviposit within a lengthy period of time.

When handled expertly this agent is relatively undangerous to man and domestic animals. Caution is called for nonetheless, because DDT collects in the fatty tissues. It is toxic to bees.

It may be employed in all plant cultures to control biting insects but its action on various species varies. Numerous species of snout beetles are more resistant. Application of this agent over a period of several years has led to the development of resistance symptoms. To-day it is being used primarily to control insect vectors, numerous anopheles species, the transmitters of malaria. *Aedes aegypti*, yellow fever mosquitoes and others, for example.

BHC

BHC stands for *b*enzene *h*exachloride. Owing to its high vapour pressure this agent, unlike DDT, possesses a strong initial effect but only a weak residual effect. In the first place BHC is a respiratory and contact poison but to a certain extent also acts as a stomach poison. If handled expertly the agent is not dangerous to man and domestic animals. Although rapidly absorbed by the human body it is decomposed very quickly. BHC is toxic to bees. The active ingredient is not a uniform substance but a mixture of several so-called isomers.

Only one of these isomers, the so-called gamma-isomer, possesses the insecticidal property. The action of the other isomers is insignificant. Furthermore, they possess a characteristic musty odour which can be taken up by the plants and fruits, thus rather limiting the uses of the isomer mixture. The gamma-isomer, on the other hand, is taste- and odourless.

We, therefore, distinguish between impure, technical BHC and gamma-BHC, also called Lindane, obtained by solvent extraction from the former and possessing 99 % purity, minimum.

The range of action of BHC is very broad. It not only controls biting but also sucking insects and even soil pests. Impure or technical BHC can be used in forestry and tree nurseries only, but Lindane formulations may be applied in all plant cultures. Owing to its versatility BHC, in technical and Lindane quality, to-day still is a very widely used agent. It can be formulated as dust, dredge, spray, fumigant, sprinkler, aerosol and seed dressing, for use in agriculture, forestry, horticulture, fruit growing, stored products and for hygiene purposes.

Summing up briefly the special properties of DDT and BHC it can be said:
DDT: slow initial effect – sustained residual effect
Gamma-BHC: rapid initial kill – short period of effectiveness.

From this it can be seen that both agents supplement each other excellently. For this reason combination agents have been formulated which possess a rapid initial effect and a long period of effectiveness. These combined DDT-BHC preparations to-day are still in wide use as dusts, sprays and space fumigants.

Toxaphene

Toxaphene also is a chlorinated hydrocarbon, prepared by chlorinating camphene. It possesses only a minimal vapour pressure, hence its volatility and initial effect are minimal but, like DDT, its residual effect and weather stability are good. It is an outstanding insecticide, suited for special treatments to control certain insect species, esp. biting insects with protracted migration periods, e.g. grass-hoppers and cotton boll weevils. At the same time it has the valuable property of sparing other species, honey bees in particular. It is, therefore, one of the few pesticides which is non-toxic to bees.

These properties permit application of the agent in blossoming plant cultures. In the first place toxaphene is a stomach poison but with good contact poison properties. It develops its full effectiveness at temperatures above 20 °C. If handled expertly toxaphene is non-toxic to man and domestic animals. The agent has also been combined with DDT and Lindane, but these formulations then are toxic to bees. Toxaphene being extremely toxic to fish, drifting to waters abounding in fish must be avoided.

Other chlorinated hydrocarbons are Aldrin and Dieldrin, two chemically closely related compounds.

Aldrin is applied chiefly as seed dressing, powder or dredge or as an additive to mercury seed disinfectants to control soil pests. Its volatility assures good distribution in the soil. Despite its high volatility it possesses a satisfactory residual effect which is said to extend over a period of one year. Aldrin is more toxic than DDT and BHC. It is toxic to the skin and very poisonous for bees. Aldrin-treated seed remnants must not be used to feed chickens.

Dieldrin, unlike Aldrin, possesses a very low vapour pressure and consequently low volatility, but a good residual effect. Like Aldrin it is used first and foremost in seed dressings and incrustation preparations to control soil pests and various vegetable flies. Formulated as a spray it is effective against biting insects only. Against caterpillars it is ineffective. It is used primarily to control grass hoppers and cotton pests. Dieldrin is a strong bee poison. If handled expertly it is not dangerous to man or domestic animals, but being toxic to the skin it must be handled with caution.

Endrin

This agent has a low vapour pressure. It, therefore, volatilizes slowly but possesses a strong residual effect which, however, does not come up to that of DDT or toxaphene. Endrin is a contact and stomach poison. It is used chiefly

to control mites and larvae of mangold flies but is also active against numerous sucking and biting insects. Since the agent is highly toxic it is applied chiefly in technical cultures such as cotton. When working with Endrin preparations great care must be exercised. Endrin is toxic to fish and bees.

Thiodan

Thiodan is a stomach and contact poison with a good range of action. It is used in all tropical and sub-tropical cultures to control weevils, caterpillars, pseudocaterpillars and sucking insects. Thiodan has a rapid initial and a relatively satisfactory residual effect. Next to toxaphene it is the second insecticidal agent with no toxic effect on bees, so that spraying and dusting may be carried out without risk in blossoming cultures when bees are not in the field. Thiodan, however, is a pronounced fish poison. If handled expertly it is not dangerous to man or domestic animals.

Organophosphorus compounds (phosphoric acid esters)

Non-systemic compounds

Parathion

This agent is a respiratory, contact and stomach poison with high vapour pressure and consequently with a rapid initial effect.

On the other hand its residual effect is small because Parathion decomposes within a few days. A supplementary feature is its intensive penetrative effect, so that insects are killed on the under leaf sides and in the leaf interior when only the upper leaf sides have come into contact with the spray liquid. The active ingredient is very toxic so that care is required in handling parathion preparations, particularly concentrated ones. Owing to its high volatility it can be resorbed through the skin or the lungs. When working with such preparations the directions for use must be strictly adhered to. Parathion is toxic to bees.

Parathion controls nearly all injurious insects in all cultures. Only few species of insects remain completely unaffected or are controlled to an insufficient degree e.g. scales. Its effect on spider mites also is unsatisfactory.

Methyl parathion

Parathion and methyl parathion are both esters of phosphoric acid, parathion being an ethyl ester and methyl parathion a methyl ester of that acid. Due to its high toxicity and vapour pressure methyl parathion has a similar rapid and lasting effect like parathion without possessing the latter's wide range of action.

Malathion

A characteristic of this phosphoric acid ester is its low toxicity for man and domestic animals. Malathion also exhibits a penetrative effect. It is a stomach, contact and respiratory poison. The agent is used chiefly to control sucking

insects in fruit and vegetable cultures. It also is effective against malaria mosquitoes and ectoparasites. The agent is toxic to bees.

Chlorthion

Chlorthion is less toxic to man and domestic animals than parathion but does not possess the latter's range of action. It acts chiefly on aphids.

Diazinon

An advantageous feature of this agent is its low toxicity to man and domestic animals, which lies between that of BHC and DDT. Diazinon possesses a rapid initial effect but only a relatively brief residual effect on living plants, whereas on dead material it remains potent for several weeks. It is, therefore, particularly well suited for the control of DDT-resistant flies. Since Diazinon has a very good penetrative action it controls aphids, fruit flies, caterpillars and spider mites particularly well.

Gusathion

This phosphoric acid ester has a good range of action and, compared with other organic phosphates, a relatively persevering residual effect. Its penetrative effect, however, is not quite so pronounced. On the other hand Gusathion is a stronger contact insecticide. It is highly toxic to man and domestic animals. The agent is used to control biting and sucking insects and spider mites in pine apple, citrus, coffee and cotton plantations and in other tropical cultivated plants, in particular. Compared with other phosphoric acid esters Gusathion is not quite so dependant upon temperatures for the development of its effect.

Trichlorphon

Trichlorphon is not an ester of phosphoric but of phosphonic acid with low toxicity to warm-blooded animals and a pronounced stomach effect. Special mention must be made of its good ability to penetrate into plants, so that not only leaf-feeding weevils (with the exception of snout beetles) and caterpillars but also stem borers, fruit flies and leaf miners are killed. Hence trichlorphon is specially suited for the control of stem and boll borers in cotton, rice, maize and sugar cane. When controlling maize stalk borers *(Busseola fusca Fuller, Diatraea sp., Pyrausta nubilalis Hb.)* granulated preparations which drop into the leaf sheaths of maize plants have a superior effect. The agent has also proved its worth in the control of hygiene pests.

Systemic phosphoric acid esters

Unlike the above-mentioned organic phosphorus compounds the following are resorbed by plant tissues above and beneath the soil surface and transported by the plant sap within the plant from the roots to the leaves and from the leaves to the fruits. In this way the active agents are distributed throughout

the entire plant without disturbing vital plant processes. They are, therefore, termed systemic or internal therapeutic agents.

The action extends to all pests which attack the plant either by sucking plant sap or by feeding on plant tissues. There also is a respiratory or contact poison effect but it is restricted to the time required by plants to absorb the agent. Within the plants the agents are decomposed to harmless substances. This process takes place more rapidly within the leaves than in the fruits. The period of effectiveness amounts to 10—18 days in general. Plant compatibility is very good.

Systemic phosphoric acid esters are toxic to bees. Bees, however, are jeopardized by contact action only till the agent has penetrated into the plant. These agents are to a great extent non-toxic to fish but not harmless to man or domestic animals, so that great care must be exercised when working with systemic preparations. The directions for use must be strictly adhered to.

Systemic phosphoric acid esters have a broad range of action. They control in differing degrees aphids, leaf suckers, woolly lice, thrips, saw flies, fruit flies, fruit worms, caterpillars of leaf roller moths, ermine moths, leaf-mining pests, leaf nematodes and spider mites. They may be applied in all tropical and subtropical cultures such as pine apple, cotton, citrus, coffee, maize, olives, rice, tea, sugar cane and others.

The following are systemic agents:

Demeton

This is a collective name for a group of systemic agents. Demeton is very volatile and highly toxic, but there are also some less toxic compounds. The spray coatings exhibit no contact action. It controls only sucking insects, saw flies and spider mites.

Phosdrin

A special feature of this agent is its short residual effect lasting 1—2 days only, so that it can be applied 4 days before crop lifting. It exhibits a good action against biting and sucking insects, leaf miners and spider mites. Phosdrin is a stomach, contact and respiratory poison. Great care must be exercised when handling this agent.

Phosphamidon

Its effect perseveres for about one week. Phosphamidon is used to control biting and sucking insects and spider mites.

Dimethoate

This agent, possessing both systemic and contact effects, has a good range of action. It may be used to control sucking and biting insects, leaf miners, fruit flies, saw flies and spider mites. It possesses a strikingly low toxicity to

warm-blooded animals. It has proved its worth particularly when applied in cotton, citrus, rice, sugar cane, paprika, olives, tobacco, coco palms and peanuts.

Insecticidal carbamates

Sevin

This agent is particularly well suited to control caterpillars and other biting insects in fruit and vegetable cultures and pests on citrus fruit, bananas, grapes, rice, sugar cane and cultures of forage plants. Sevin is particularly effective against numerous cotton pests such as the cotton boll weevil *(Anthonomus grandis Boh.)*, pink boll worm *(Platyedra gossypiella Saund.)*, cotton leaf worm *(Alabama argillacea Hbn.)*, lygus bugs and others.

The low toxicity to man and domestic animals is a great advantage of this agent. The LD 50 for rats p.o. is 540 mg/kg. In the United States a tolerance of 10 ppm for apples, pears, beans and grapes has been fixed. The time between last application and harvest also is remarkably short, 7 days being considered sufficient, so that Sevin may be applied immediately prior to crop lifting.

Sevin, however, is toxic to bees. It may be mixed with other insecticides and fungicides but admixture of alkaline substances should be avoided. With apples Sevin may cause fruit drop if applied too early in the season, hence it should not be sprayed till four weeks after petal fall.

Insecticides from plant materials

These insecticides are mentioned only for the sake of completeness. But for one exception they no longer have any practical significance. They are applied in rare instances only, nowadays. This group includes nicotine, derris and quassia.

The above-mentioned exception is pyrethrum. The active insecticidal constituents are pyrethrins and cinerins. They are obtained by extracting flower heads of *Chrysanthemum cinerariaefolium Trev.*

The very good action of the pyrethrins, expressed by their high toxicity to insects, even in great dilution, coupled with non-toxicity to man and domestic animals of such quantities as are used in practice has, as yet, not been surpassed by most synthetic insecticidal agents. The development of tolerance for DDT and other agents by various insect species and the fact that DDT collects in human fat has led again to an increased use of Pyrethrum for controlling health pests in closed rooms (flats, hospitals, chocolate and food industry, sausage factories and butcheries).

Pyrethrum is a contact poison with strong initial but only short residual effect. By adding synergists (sesamine, piperonyl butoxide, sulfoxides etc.) the potency of pyrethrum can be increased 4—10-fold and the period of effectiveness, in absence of light, extended to 7 days.

(3) Acaricides

Application of non-systemic phosphoric acid esters against spider mites over a period of several years has shown that the latter, with their rapid sequence of generations, gradually grow resistant to phosphoric acid esters. Specific acaricidal agents with a strong initial and a satisfactory residual effect have, therefore, been developed, which – though not quite uniformly – not only destroy adult spider mites and larvae but, by killing the young spider mites shortly prior to or during hatching, also destroy the summer and winter eggs. The acaricidal agents have little or no effect on insects or spider mite predators so that the biological equilibrium necessary to prevent spider mite mass multiplication is not disturbed.

A distinguishing feature of acaricides is their low toxicity to warm-blooded animals, good plant tolerance and, above all, their non-toxicity to bees.

The most important agents with specific acaricidal effects are: Benzene sulfonate, chlorocide, dinitroalkylphenylacrylate, Kelthane, Tetradifon, tetrachlorodiphenylsulfide.

These agents, however, differ in their action, some being less effective against eggs than against adult spider mites and larvae and vice versa. Benzene sulfonate, Tetradifon, for example, act in the first place on summer eggs, chlorocide and Kelthane on larvae and fully-developed spider mites, whereas tetrachlorodiphenylsulfide is said to be a specific agent for winter eggs and larvae hatching therefrom. In citrus and cotton plantations it is recommended to use acaricides in rotation with phosphoric acid esters.

(4) Nematicides

During the last few years good progress was made in developing nematicidal agents, so that to-day a number of useful substances is at our disposal for controlling root knot, stem and leaf eel worms and both cyst-forming and not cyst-forming nematodes. They are applied as liquids with an active vapour phase and as solids. Some nematicides also exhibit activity against soil fungi and germinating weed seeds. They can, therefore, be applied to control damping-off and foot rot and wilt diseases.

The following are nematicidal agents:

Chloropicrin

Besides its nematicidal activity chloropicrin also possesses bactericidal, fungicidal and herbicidal properties. As a nematicide it acts on root knot eel worms and nematodes living in the open. It is phytotoxic, however, so that it cannot be applied on cultivated soil. Economic application is possible in hot houses, seed beds, compost and planting soil. After treatment a pause of 4—6 weeks, its length depending upon soil texture and temperature, must be observed. Owing to its high toxicity the application of chloropicrin is subject to special regulations.

D-D (dichloropropane and dichloropropene)

The agent may be used to control nematodes in hot houses and free-living not cyst-forming nematodes in the fields.

D-D also performs excellently against cyst-forming nematodes. It is highly toxic to man and animals. It must not come into contact with the eyes or the skin. Furthermore it is inflammable. Application is effected with injectors. The treated area should first be allowed to rest for about a week and then the escape of D-D gas promoted by soil cultivation measures (ploughing). 6—8 weeks must elapse before the soil may again be cultivated. Planting must be delayed till the odour of the agent is no longer perceptible.

Vapam

This agent, possessing nematicidal as well as bactericidal, fungicidal, insecticidal and herbicidal properties, has a broad range of action. Vapam is applied in the liquid state, the gas being liberated in the soil. After application the soil must be well covered, the cover being lifted after seven days to allow the vapours to escape more quickly. A waiting period of 4—5 weeks must be observed. Vapam is a skin, eye and mucous membrane irritant, great care must, therefore, be exercised when handling it. During work a respiratory mask should be worn.

Methylisothiocyanate

It controls root knot eel worms and free-living nematodes. With cyst-forming nematodes only a reduction in the severity of attack is obtained. Methyl isothiocyanate is a solid agent dissolved in a solvent. It is less toxic than other nematicides, but irritates the skin and the eyes. In the soil it immediately volatilizes and spreads as a gas.

Methyl isothiocyanate is employed to disinfect soil for culture raising and compost soil in hot houses and in the field. Treated areas must be covered up so that the agent cannot evaporate prematurely. One week after treatment the soil must be loosened. After 3—8 weeks, depending on soil temperature, the plot or seed bed soil may again be cultivated.

Mylone

This agent is a white powder compounded with a carrier to give a dredge. Mylone is little toxic and has no unpleasant irritant properties. For soil disinfection the agent is mixed with the soil, in the field it is worked into the ground. During treatment the soil surface must be well moistened. Depending upon soil temperature 3—8 weeks must be allowed to elapse between treatment and cultivation. The agent is particularly effective against root knot eel worms and free-living nematodes. Germinating weed seeds also are affected.

Nemagon

This new nematicide (Dibromochloropropane) is either injected into the soil or first distributed in granular form and then worked into the soil. Its vapour

pressure is very low so that agent losses are minimal. Being effective at high temperatures only Nemagon is particularly suited for the control of nematodes in tropical cultures, bananas for example. In view of its minimal phytotoxicity it can be applied in very many cultures.

When working with Nemagon the producer's directions for use must be strictly adhered to, otherwise succeeding cultures may suffer heavy injuries and health hazards for man may arise.

(5) Molluscicides

Metaldehyde

Metaldehyde is a white, crystalline taste- und odourless powder with a specific action on slugs. It is a stomach and contact poison but has no attractant properties. After imbibing the poison the slugs show symptoms of paralysis and generate excessive amounts of slime. Slug species differ in their susceptibility to the agent.

The agent is mixed with wheat bran to a solid dry bait which is distributed in little heaps or spread between plants. By means of various additives the bait effect can be improved. The baits, however, are very sensitive to moistnre. Granulated bait preparations usually contain an agent to suppress development of fungi thus extending their effectiveness. Metaldehyde can also be applied as a dust or spray. These formulations are particularly suited for marginal or row treatment. However, the plants must not come into contact with the agent. Dead slugs should not be fed to chickens but buried or burned instead.

(6) Rodenticides

Red squill

There are two types of botanically identical squill species, a red and a white one, which differ only in the red dye content in the outer squill skins and in the composition of certain chemical constituents. Both contain strong poisons but only the red species possesses a specific rat poison which is also a useful cardiac drug in human medicine. Certain rodents and rats in particular, have a high degree susceptibility, specific to the species, for this poison. With them alone it acts as a nerve poison causing heavy convulsions with subsequent exitus.

In practice only liquid red squill extracts are used for control treatments. They are mixed with or sprinkled on suitable baits according to the directions for use.

α-Naphthylthiourea (ANTU)

In the first place ANTU is a poison for Norway rats. It is applied as a powder or bait or added to water at watering places. The best effects are obtained with high concentration preparations (50% and 98—100%) only. It attacks the blood vessels by rendering them permeable so that the blood discharges into the brain or lungs. ANTU is toxic to cats and dogs.

Zinc phosphide

This agent is used in powders and pastes for home-made baits or in ready-for-use poison baits to control rats, pine and field mice. It has a characteristic smell of carbide. Zinc phosphide is highly toxic to domestic animals esp. poultry.

Coumarin derivatives

These agents initiated a revolution in rodent control. The use of strong poisons in rat control has decreased considerably in consequence.

Coumarin derivatives inhibit the synthesis of prothrombin, a blood constituent of paramount importance for the vital process of blood coagulation and concurrently damage the blood vessels, so that internal haemorrhages form. The rats do not feel the poison effect. Their exitus takes place under physiological circumstances completely different from those obtaining after employing all other poisons. The poison must be taken up by the rodent in the course of several days in several small doses to develop its effects. This is secured by the fact that the rats perforce repeatedly walk along the dusted runways, where the poison clings to their fur or paws whence, owing to their pronounced sense of cleanliness, it is licked off continually.

The poison, a practically white, odour- and tasteless powder, is mixed with a carrier. It can be applied as a dredge or bait or is added to water at the watering places. Whole towns and villages have been cleared of rats with this poison.

Chlorinated hydrocarbons

It was found that the chlorinated hydrocarbons Toxaphene and Endrin prove very effective against field mice and voles. In calamities large-scale control of these small rodents can be carried out with these agents which, first and foremost, are insecticides. They are applied by spraying or dusting. The time which must be allowed to elapse between last application and utilization of the green plants is 42 days. They may be used at certain times and in concerted extermination campaigns only. Inexpert handling of these agents jeopardizes wild game. Both agents are highly toxic to fish.

(7) Herbicides

Herbicides may be classified according to their mode of action as follows:

- Non-selective (total) herbicides
- Selective herbicides
  - contact herbicides
  - growth regulating (hormone-type) herbicides
  - non-hormone-type herbicides

Non-selective herbicides

Non-selective herbicides are chemicals which act aggressively on all plants, killing them more or less completely. Such herbicidal agents, but for a few exceptions, cannot be applied in plant cultures. They may, however, be used to clear areas with heavy weed infestation if a lengthy period of time is allowed to elapse between treatment and cultivation or planting. Other possible sites of application are paths, sports grounds, rail beds, factory sites, airfields, tank reservoirs etc.

The following are active agents of total herbicides:

Chlorates

The most prominent representative of this type is sodium chlorate but the potassium salt is also used to control forest weeds. Chlorates are the prototype of all-round "killers".

They are toxic to all plants, killing both seed weeds and root weeds. They act chiefly by way of the roots but also penetrate through the leaves. Chlorates contain oxygen and thus promote combustion without themselves being combustible except in conjunction with inflammable materials. Chlorates are relatively non-toxic to man and domestic animals. 6—8 months must be allowed to elapse between treatment and cultivation. They should be scattered on well-moistened soil.

Trichloroacetate (TCA)

This agent is absorbed by plants and in practice is chiefly used to control grasses on waste lands and pastures, weeds in dry ditches and fish ponds and in forestry for grass control on cleared sites. Limited application in agriculture and stone-fruit plantations is feasible.

Application must be effected before the grasses sprout, in some cultures before planting or sowing or after harvesting field crops. TCA is practically harmless to man and domestic animals but may cause skin irritation. It possesses the advantage of decomposing more rapidly in the soil than the chlorates, the time required – approx. 16 weeks – depending upon soil-type, bacterial activity and rainfall. In soil with compressions in the root zone decomposition is too slow, hence TCA should not be used in such cases. It should be applied on well-moistened soil.

Dalapon (DCP)

This agent, unlike TCA, must be applied on growing plants. Its decomposition in the soil is effected by micro-organisms, the process requiring 8 weeks on the average. Like TCA, Dalapon acts specifically on monocotyledons. In forestry it may be used to control grasses on clear fellings before re-forestation, in drainage canals and on the banks of stagnant or flowing waters. By adding growth regulators dicotyledons may be controlled simultaneously. Dalapon is practically harmless but sensitive persons may suffer skin irritations.

Aminotriazole

The agent is absorbed by the leaves. It can, therefore, be applied during the vegetative period only. It acts very quickly, chlorosis showing on the weeds within a few days. It is translocated by the sap stream from the leaves to the roots so that even tenacious rhizome weeds are destroyed. Being non-flammable aminotriazole is a total herbicide well suited for application on timber and tank storage places, rail beds, industrial sites and for the destruction of undesirable plants on ditch banks, highways and public squares. In the soil it decomposes rapidly. It is not acutely toxic to man or domestic animals.

Selective herbicides

Contact herbicides

Contact herbicides act by corroding or scalding overground green plant parts coming into direct contact with the spray liquid. When spraying dry plants this takes place very rapidly. Damage of the leaf surface to such an extent that the unwetted parts are unable to maintain viability is a necessary prerequisite for destruction of a weed plant. Underground parts (roots, rhizomes etc.) remain unaffected.

For this reason corrosive herbicides are in general only suited to destroy annual, hibernated and biannual seed weeds.

Corrosive herbicides are chiefly used in grain and various special cultures. Their selective action is essentially due to the fact that the drops of spray liquid run off of cultivated plants, which are either wax-coated or possess upright leaves (grain), but adhere to broad-leaved weeds with their horizontal leaves and there destroy the plant tissue. However, it must be borne in mind that corrosive herbicides may be applied only during a certain stage of development of the cultivated plants and under certain climatic conditions.

The main corrosive herbicides are:

Nitrophenols

These include DNOC (dinitro-o-cresol) for controlling weeds in corn cultures and DNPB (dinitro-o-sec.-butyl phenol) for weed control in legumes.

The nitrophenols are effective against young seedling weeds only. They are highly toxic to man, domestic animals, bees and fish.

Pentachlorophenol (PCP)

This agent is applied before cultivated plants emerge and helps to avoid costly, time-robbing hoeing and weeding operations. Only seeds with a long germination period may be treated with PCP. It destroys seed weeds developing before cultivated plants emerge. Application during the vegetation period is possible if the operation is carried out in such a way that cultivated plants do not come into contact with the spray liquid. The agent is toxic to man and domestic animals. It irritates the skin and mucous membranes.

Growth regulator herbicides

These agents are synthetic growth regulators acting in the same way as hormones synthesized in plants. After application of these agents hormone overdoses affect the growth of plants, giving rise to various kinds of pathological changes in shape such as stem thickenings, stem lesions, sprout distortions, development of air roots, leaf deformations and distortions and other malformations. In these deformations the plants use up their nutrients without possessing the necessary assimilation capacity for accelarated growth and thus exhaust themselves and die.

Penetration of weed plants by hormone-type agents is rapid. They are absorbed by the leaves or through the roots and distributed within the entire organism thus enabling the destruction of perennial weeds.

Small grains, sorghum, millet, rice, sugar cane and grasses being tolerant to larger quantities of growth regulators, the latter have become selective herbicides for monocotylic cultivated plants. Another fact favouring cultivated plants is that they are more difficult to wet than broad-leaved weeds. Furthermore, their sensitive vegetation points lie sheltered. However, a number of monocotyledons also can be controlled with hormone-type herbicides. Thus MCPA may be used in peanut and coffee plantations.

From the mode of action of hormones it follows that they should be applied when weeds are in the growing stage and when growth-promoting weather conditions prevail. In small grain cultures application is feasible in the period between development of fresh shoots and ear or panicle formation. The quantities recommended for use must not be exceeded. When working with hormones care must be taken not to jeopardize dicotylic cultivated plants by drift. Hormones are non-toxic to man and domestic animals. Bees also are not affected.

The various hormones differ in their action both on cultivated plants and weeds. The directions of the producers must, therefore, be followed in all cases.

The following growth regulators may be applied:

2,4-D (2,4-Dichlorophenoxyacetic acid)

MCPA (2-Methyl-4-chlorophenoxyacetic acid)

CMPP (4-Chloro-2-methylphenoxypropionic acid)

MCPB (α-(4-Chloro-2-methylphenoxy)-butyric acid)

2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)

Hormones have also been combined with each other. They are either of liquid or solid consistency.

Non-hormone-type herbicides

Carbamates

These agents are absorbed chiefly by germinating seeds. They are held back in the upper soil layers and there destroy germinating weeds. Their effect on older weeds past the cotyledon stage is unsatisfactory.

Carbamates are applied after sowing and before the emergence of the cultivated plants. The seeds must, however, lie at least 2 cm below the soil surface. Most of the early-germinating annual seed weeds and annual grasses are affected. Late germinating seed and root weeds cannot be controlled with carbamates. They should be applied on moist soil. Drought seriously impairs their action.

The best-known carbamate is:

CIPC (3-Chlorophenyl-isopropyl-carbamate)

It is practically non-toxic to man, domestic animals and bees.

Urea derivatives

Unlike the carbamates these agents are absorbed exclusively by way of the roots. Like the carbamates they are little soluble in water and remain in the top soil layers for some time. Urea derivatives kill nearly every plant whose roots they come into contact with, so that they can also be used on highways, public squares and industrial sites.

The following are the chief representatives of the group of urea derivatives:

DCMU (3-(3,4-Dichlorophenyl)-1,1-dimethylurea)

CMU (3-(4-Chlorophenyl)-1,1-dimethylurea)

They are practically non-toxic to man and domestic animals.

Triazines

The best-known and in practice most widely used triazine compounds are Simazin and Atrazin.

Simazin

Simazin is insoluble in water and a pronounced root herbicide. The absorption of this agent by plants is coupled with the nutrient and water uptake. The time of application and soil moisture conditions at that time are decisive factors for good performance. In very dry soil it is held back in the top layer and remains impotent as a root herbicide if there is no rain to wash it down to the root zone of the weeds. Weeds possessing deep-seated roots or perennial weeds are not affected by this agent. If Simazin is applied at the proper time to soil still uninfested by weeds germinating seeds of seed weeds are killed within a short period of time. The effect rests upon the inhibition of the conversion of photoenergy into chemical energy.

Simazin is very versatile. It may be used as a selective agent to control germinating seeds in susceptible cultures such as vine plantations, fruit and berry plantations, asparagus plantations (pre-emergence application), in forest and fruit tree nurseries and in ornamental shrub plantations.

Excellent application possibilities are afforded by the pre-emergence treatment of maize which, being able to decompose the agent, is genuinely tolerant to Simazin. Simazin may also be used in pre-emergence treatment of cotton, sorghum and sugar cane. The protracted residual effect of Simazin is

also very useful, allowing suppression of weeds for a whole vegetation period with but a single treatment. However, owing to the great stability of the agent the subsequent cultures are jeopardized to a certain extent, particularly in cases of overdosing. Rates of application recommended by the producers should never be exceeded.

Atrazin

Unlike Simazin, Atrazin is also absorbed through the leaves. The leaves begin to yellow. Seedlings are least tolerant, being killed by very small doses. The agent possesses a broad range of action against monocotyledons and dicotyledons, but tolerances differ. Maize is physiologically tolerant of this agent, too. Atrazin, being more water soluble than Simazin, enters the soil more quickly. A high humus or clay content lowers the initial and residual effect. It also is less weather-dependant than Simazin. Owing to this fact, coupled with its higher water solubility and absorption through the weed leaves Atrazin can be used in arid regions for pre- or post-emergence treatment of maize. Both Simazin and Atrazin are practically non-toxic to man and domestic animals.

F. TOXICITY OF CHEMICAL CONTROL AGENTS

To prevent health hazards to man by chemical plant protectants and pesticides and to exclude dangers of any kind during practical application every preparation is tested for its toxicity.

In practice there always is a chance of small quantities of chemical control agents getting into the stomach when eating with unclean hands or into the body through the skin when preparing spray liquids or into the lungs by inhalation during spray treatment.

The toxicity is determined by means of animal tests. The agent or preparation is applied to test animals – usually rats – in differing quantities in aqueous solution, emulsion or suspension.

Application may be effected
orally resp. perorally – the substance is administered through the mouth,
cutaneously resp. subcutaneously – absorption is effected through the skin,
by inhalation – gaseous poisons are absorbed during respiration.

LD 50

With every mode of application, the nature of the symptoms of poisoning, their time of onset and abatement and the exitus of the test animal are registered. Calculation of the lethal dosis required to kill 50 % of the test animals is the quantitive result of the experiment. This quantity of active ingredient or preparation is termed LD 50. The quantity causing the death of half the test animals is expressed in mg/kg body weight (1 mg = 1/1000 gram).

The following table contains the LD 50 for rats of some of the chief agents:

Insecticides	Endrin	25 mg/kg	Phosphamidon	17 mg/kg
	Aldrin	50 mg/kg	Gusathion	15—25 mg/kg
	Thiodan	50 mg/kg	Demeton group	40—100 mg/kg
	Toxaphene	69 mg/kg	Diazinon	210 mg/kg
	Dieldrin	80 mg/kg	Dimethoate	300 mg/kg
	Lindane	125 mg/kg	Sevin	540 mg/kg
	DDT	250 mg/kg	Trichlorphon	625—1,000 mg/kg
	Chlordane	457 mg/kg	Chlorthion	625 mg/kg
	Phosdrin	5 mg/kg	Malathion	1,500 mg/kg
	Parathion	6.4 mg/kg		
Acaricides	Trithion	30 mg/kg	Chloro-benzilate	4,850 mg/kg
	Kelthane	750 mg/kg	Chlorocide	10,000 mg/kg
	Benzene sulfonate	2,000 mg/kg	Tetradifon	15,000 mg/kg
Fungicides	Karathane	714 mg/kg	Maneb	7,500 mg/kg
	Thiuram	865 mg/kg	Ferbam	11,000 mg/kg
	Ziram	1,450 mg/kg	Captan	15,000 mg/kg
	Zineb	5,700 mg/kg		
Herbicides	Arsenites	13 mg/kg	Aminotriazole	1,100 mg/kg
	DNOC	26 mg/kg	Atrazine	3,000 mg/kg
	DNBP	35 mg/kg	TCA	3,370 mg/kg
	PCP	210 mg/kg	CIPC	3,800 mg/kg
	2,4-D	375 mg/kg	Simazin	5,000 mg/kg
	2,4,5-T	400 mg/kg	DCP	7,000 mg/kg
	MCPA	700 mg/kg		

The figures illustrate the toxic effects of the various agents: The bigger the figures the lower the toxicity of the agent.

In addition to the determination of the LD 50 the control agents are also tested for their cumulative toxicity (accumulation of agent in the organism). For this purpose equal doses are administered to the test animals every day per os or the animals exposed to a certain concentration of agent in the air for several hours each day. Food uptake, general condition and weight of the test animals are registered, and blood and urine tests and functional tests carried out. The internal organs of test animals dying during the test are examined carefully. In feeding tests extending over several months the quantity of agent or preparation which a test animal may imbibe without falling ill or suffering organic changes is thus determined exactly.

Chemical agents also have certain effects on plants (phytotoxicity). Some active agents or additives in preparations engender spot formation on plants or symptoms of wilt or even cause death of the plants. The applicability of plant protectants in cultures of cultivated plants thus may differ. The differing reactions of plants to plant protectants are governed by their morphological nature or by physiological factors. In many instances phytotoxic damages can be traced to faulty methods of application, e.g. overdosing or wrong timing

of treatment. In all cases the range of action and application methods such as concentration, time of application etc., recommended by the manufacturers, should be taken into consideration.

G. TOLERANCES FOR CHEMICAL CONTROL AGENTS

How much of a chemical control agent remains on harvested crops after treatment? What are the effects of these residues on the human body?

These questions are justified since many harvested crops still contain residues of the applied agents. However, if the directions for application are observed there is no danger to the human organism whatsoever.

Every registered pesticide is tested in animal experiments on its compatibility with man or domestic animals before being used in practice. In addition the preparations are first tested on those crops in which they are to be used for control treatment later. At certain time intervals residues are determined by biological, chemical and physical methods. It must also be borne in mind that after treatment with a chemical agent plants begin to decompose the latter chemically. Furthermore a certain proportion is washed off by rain and the sun induces accelarated evaporation of the agent. Plant growth also has a natural diluent effect. Thus the quantity of agent on the plant decreases day by day so that residues still remaining on the crop when crop lifting begins are without any significance and harbour no danger.

Up to now there exist only few legal regulations relating to pesticide residues. Most countries follow the pattern of US legislation fixing maximum levels for pesticide residues. In the US a law was enacted for the protection of the consumer fixing tolerances in foods which, according to scientific investigations, are considered harmless to man.

Animal experiments again provide the necessary basis. First the quantity of agent causing first symptoms of poisoning in the test animal is determined. Next that quantity is determined which does not lead to any symptoms of poisoning. The value so obtainded provides the necessary basis for calculation. 1 % of this value is taken and reduced to the average human body weight. Thus only 1 % of the quantity which is proven to be harmless to the animal is considered to be without hazard to man.

The fixed tolerances are expressed in ppm (parts per million). In our case this is mg/kg of food, vegetable or fruit. The following table contains the permitted residues (tolerances) of the principal active agents.

agent	tolerance, ppm	agricultural products
Aldrin	0.25	apricots, grape fruit, tangerines, lemons, oranges, shaddock, peanuts,
	0.1	pine apple, mango, melons, nectarines, egg plant, pepper, rice, tomatoes
	0	beans, millet. maize, soybeans
Captan	100	pine apple, apricots, apple, grape fruit. almonds, mango, lemons, egg plant, soybeans
Chlordane	0.3	pine apple, apple, apricots, grape fruit, tangerines, melons, shaddock, oranges, lemons, batatas, beans, maize, egg plant, tomatoes, peanuts
DDT	7	pine apple, apricots, citrus fruits, mango, melons, nectarines, grapes, beans, cucumber, egg plant, tomatoes, peanuts, pepper
Demeton	0.75	apricots, grape fruit, tangerines, melons, oranges, lemons, pepper, tomatoes
	0.3	beans
Dieldrin	0.25	pine apple, bananas, grape fruit, tangerines, oranges. lemons
	0.1	apricots, mango, nectarines, batatas, rice, egg plant. pepper, tomatoes
Diazinon	1.0	olives
	0.75	apricots, figs, melons, nectarines, oranges, lemons, beans, cucumber. pepper, tomatoes
Endrin	0	egg plant, pepper, tomatoes
Ferbam	7	apricots, citrus fruits, dates, mango, melons, nectarines, beans, peanuts, pepper, tomatoes, maize, egg plant
BHC	5	pine apple, apricots, citrus fruits, mango, melons, nectarines, grapes, beans, maize, egg plant, pepper
Kelthane	10	grape fruit, tangerines, nectarines, oranges, lemons, shaddock
	5	pepper, egg plant, beans, tomatoes, figs, melons, walnut
Lindane	10	pine apple, apricots, citrus fruits, mango, nectarines egg plant, beans, maize, pepper
Malathion	8	pine apple, apricots, dates, figs, grape fruit, mango, oranges, walnut, lemons, shaddock, millet, rice, peanuts, egg plant, beans, tomatoes
	2	maize

agent	tolerance, ppm	agricultural products
Methoxychlor (DMDT)	14	pine apple, nectarines, egg plant, beans, peanuts, maize, pepper
Methyl bromide	200	cashew nuts, peanuts, almonds, chestnut, walnut
	75	batatas
	50	beans, millet, cocoa-beans, maize, rice, sweet corn
	30	grape fruit, tangerines, oranges, lemons, pepper, batatas, manioc, yam roots
	20	pine apple, egg plant, mango, melons, nectarines, grapes
Phosdrin	1	millet
	0.25	egg plant, beans, maize, pepper, tomatoes
	0.5	apple, grapes
Parathion	1	pine apple, citrus fruit, dates, figs, mango, melons, nectarines, olives, egg plant, peanuts, maize, pepper rice
Pyrethrins	3	maize, rice
	1	beans, peanuts, millet, cocoa, beans, almonds, pine apple, figs, mango, melons, oranges
Sevin	10	apple, pear, beans, grapes
Toxaphene	7	apricots, grape fruit, tangerines, oranges, shaddock, lemons, egg plant, beans, peanuts, maize, pepper. tomatoes
	5	millet, rice
	3	bananas
Zineb	7	apricots, citrus fruits, mango, melons, nectarines, egg plant, beans, peanuts, maize, pepper, tomatoes
Ziram	7	egg plant, peanuts, beans, apricots, pepper, tomatoes

These figures give an idea of the toxicity of individual agents: the lower the cited figures for an agent the higher its tocixity.

H. MINIMUM INTERVALS BETWEEN LAST TREATMENT WITH CHEMICAL CONTROL AGENTS AND HARVEST

In addition to the fixing of tolerances for pesticide residues the consumer of agricultural products can be protected in yet another way by fixing waiting periods. This means that a period of time is fixed which must be observed between application of a pesticide and harvest of treated food plants. Within this period the active ingredient of the control agent is decomposed or has reacted so that, provided the control measure has been carried out expertly, no resi-

dues of active agent are found after this time or the residues still present are harmless to man and animals. The following waiting periods may serve as a guide for users of chemical agents:

agent	time interval (days) to be observed after treatment in		
	fruit-growing	vegetable growing	agriculture
Chlorinated hydrocarbons:			
Aldrin	30[1])	30[2])	30[3])
Chlordane	30	30[2])	30
DDT	30	30	30
Dieldrin	30[1])	30[2])	30
BHC tech.	applied in forestry only		
Lindane	30	21	21
Toxaphene	30	30	30[3])
Org. phosphorus compounds:			
Chlorthion	7	7	7
Demeton-methyl	21	21	21
Diazinon	10	10	10
	applied as a drench	30	
Dimethoate	14	14	14
Gusathion	14	14	14
Malathion	7	7	7
	cucumber	4	
Parathion	14	14	14
Parathion-methyl	14	14	14
Phenkapton	14	14	14
Phosdrin	4	4	4
Trichlorphon	10	7	10
Acaricides:			
Benzene sulfonate	14	14	14
	cucumber	7	
Chinothionate	14	14	14
Chlorocid	14	14	14
	cucumber	7	
Kelthane	14	14	14
Tetradifon	14	14	14
	cucumber	7	
Tetrachlorodiphenylsulfide	14	14	14

[1]) In strawberries only before flowering and after the harvest
[2]) Not in carrots, radishes and red radishes
[3]) 42 days after area treatment for control of field mice

agent	time interval (days) to be observed after treatment in		
	fruit-growing	vegetable growing	agriculture
Fungicides:			
Captan	3	7	7
Karathane	21	21	21
	cucumber	7	
Ferbam, Maneb, Zineb,			
Ziram	7	3	7
Thiuram	7	3	7

No special restrictions have been fixed for copper, sulfur, lime-sulfur mixture, derris, pyrethrum, and quassia.

Mercury compounds may be used before flowering time and as seed disinfectants only.

VIII. HANDLING OF CHEMICAL CONTROL AGENTS

A. PREPARATION OF SPRAY LIQUIDS

To make up spray liquids from wettable powders the requisite quantity of powder must first be stirred in a vessel with a little water to form a paste without clots. The required quantity of water is then added with continuous stirring.

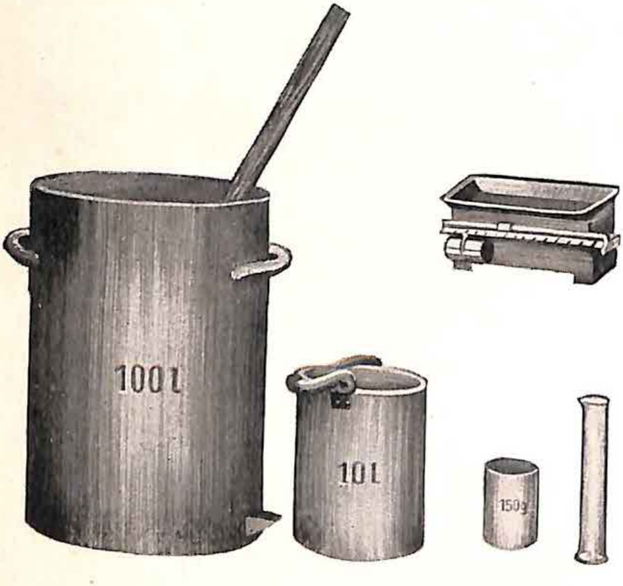


Fig. 33. Measuring apparatus for making up spray liquids

Emulsion sprays, too, are prepared by first stirring the requisite quantity for application with ca. double its weight of water and then gradually diluting with water with continuous stirring (figs. 33 to 36).

Fig. 34. Measuring out spray liquid

Fig. 35. Making up of spray liquid

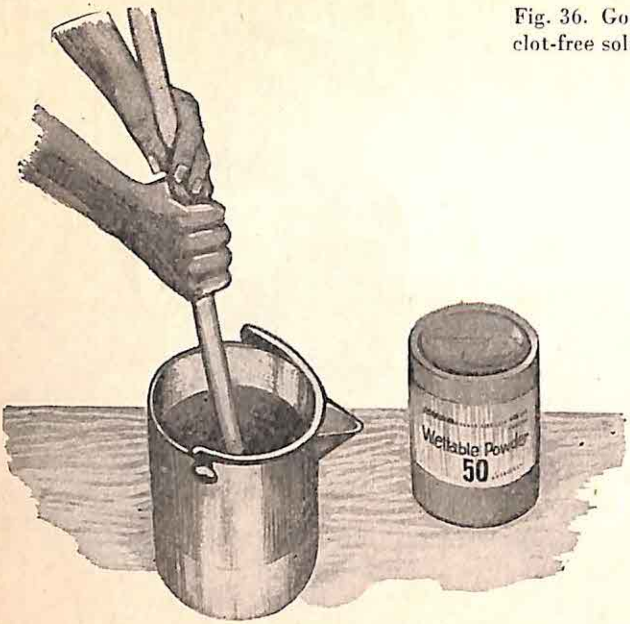


Fig. 36. Good stirring guarantees clot-free solutions

In the case of wettable powders the concentrations printed on pesticide containers signify grams or kilos per 100 litres of water but c.c. per 100 litres of water for liquid spray agents. They are valid for spray implements for field cultures with a spray capacity of 600 litres per hectare only. The same concentrations also relate to tree and shrub-like cultures such as bananas, cotton, citrus fruits, coffee, tea and others if 2,000—4,000 litres of spray liquid are applied per hectare.

Every departure from the stated quantities of spray liquid, esp. when using spray implements with a spray capacity of only 100—200 litres per hectare, necessitates a change in the recommended concentrations. When altering the quantity of water to be applied per hectare, it must always be borne in mind that the same quantity of control agent must be applied to the area under treatment nonetheless.

Concentrations will, therefore, rise.

To calculate the necessary concentrations when using spray implements the following procedure is adopted:

Divide the requisite quantity of spray liquid per hectare required when spraying with normal concentrations by the quantity applied per hectare when atomizing and multiply the normal spray liquid concentration with the factor thus obtained. This gives the concentration for the atomizing procedure, viz. the quantity of control agent in 100 litres of water.

This is best illustrated by an example:

In the past 2,000 litres of a 0.1% spray liquid were required per hectare to spray a cotton field but in future only 200 litres of liquid are to be distributed per hectare.

What must be the concentration in the 200 litres?

$$\frac{2000 \cdot 0.1}{200} = 1\%$$

The following table contains the required quantities of spray liquid for field cultures (area treatment) when using implements with different spraying capacities per hectare.

How many g or c.c. of spray agent must there be in 100 litres of spray liquid when the spray implement distributes 600, 400, 200 or 100 litres per hectare?

when applying 600 l/ha		required quantity to make up 100 l of spray liquid when spraying					
authorized conc. in %	quantity in g or c.c.	600 l/ha g, c.c.	500 l/ha g, c.c.	400 l/ha g, c.c.	300 l/ha g, c.c.	200 l/ha g. c.c.	100 l/ha g, c.c.
1.0	6,000	1,000	1,200	1,500	2,000	3,000	6,000
0.75	4,500	750	900	1,125	1,500	2,250	4,500
0.6	3,600	600	720	900	1,200	1,800	3,600
0.5	3,000	500	600	750	1,000	1,500	3,000
0.4	2,400	400	480	600	800	1,200	2,400
0.3	1,800	300	360	450	600	900	1,800
0.2	1,200	200	240	300	400	600	1,200
0.1	600	100	120	150	200	300	600
0.075	450	75	90	112.5	150	225	450
0.05	300	50	60	75	100	150	300
0.03	180	30	36	45	60	90	180
0.02	120	20	24	30	40	60	120

B. MEASURES TO BE ADOPTED PRIOR TO AND AFTER USING CHEMICAL CONTROL AGENTS

Numerous chemical control agents are toxic to man or domestic animals only when applied or stored inexpertly or carelessly. The following precautionary measures must be observed on principle:

Chemical control agents should be bought in authorized institutions only, where guaranteed expert advice may be obtained. When two agents have equal

effects and the same range of application then the more harmless one should be preferred to the toxic one.

Only trustworthy, physically and mentally healthy persons should be charged to work with control agents. Before beginning with the job read the precautionary measures printed on the package label and the enclosed directions for use. Point out precautionary measures to untrained persons. Juveniles should not be employed to work with toxic chemical control agents.

Spray liquids should be made up in the open, not in inhabited or other rooms. Care should be taken not to prepare more spray liquid than is absolutely necessary.

Do not use kitchen utensils, watering pails or feed buckets for preparing spray liquids. Use only certain marked buckets and implements which must be cleaned thoroughly after use. Avoid spilling of agents or spray liquids. Keep children and domestic animals away from spray liquids. Spray liquid residues should not be left standing uncovered over night.

Do not eat, drink or smoke when preparing and applying spray liquids. Wear protective clothing, if possible, and solid shoes (preferably rubber boots). Poisons may enter the body through the mouth, the nose and the skin (protective clothing, masks). After work, particularly before eating and drinking, wash hands and face.

When applying control agents take note of the wind direction. Drift of the spray or dust jeopardizes neighbouring forage crops, flowering cultures, men and domestic animals.

Empty packages or containers should be burned or buried. Agent or spray liquid residues or water used to rinse the implements should not be poured or emptied into rivers, brooks or ponds. To prevent domestic animals being poisoned spray liquid residues also should not be poured out along the way-side. Spilled agents or spray liquids should be covered with earth.

In cases of nausea, vomiting, shaking, head-ache, dizziness, sudden perspiration during or after work with chemical control agents stop working and call a doctor. Take off overalls, clean skin with soap and water. Do not take or administer alcohol or milk.

Chemical control agents should be stored in the original containers only. Do not refill into other vessels, bottles, paper bags or card-board boxes. Never store food or foodstuff or eating and drinking utensils together with plant protection agents.

The preparations should always be stored securely locked (chest, cupboard), in an uninhabited, separate room. It is advisable not to store large quantities exceeding the requirements for one vegetation period. The products do not improve when stored for several years. Order and cleanliness to a great extent preclude accidents due to mistakes.

Upon careful observation of all precautionary measures nobody need be afraid of working with and handling toxic chemical control agents.

C. STORAGE OF CHEMICAL CONTROL AGENTS

In agriculture, horticulture, special cultures and forestry large quantities of chemical control agents are needed to control injurious animals and plants.

In tropical and sub-tropical areas the quantities applied in field cultures are larger than those in the same cultures in Europe. Cotton cultivation, for example, is one of the biggest insecticide consumers. Up to thirty treatments are carried out during a single vegetation period. 100,000 tons of insecticide dust are used every year alone in Mexico with its 1,000,000 hectares of cotton.

Control agents must be produced in time, so that they are at hand when pest calamities threaten. This necessitates proper storage. With inexpert storage there is not only the danger of agents spoiling but also of injuries to man and domestic animals due to careless handling, ignorance and malevolence.

To secure public safety several countries have enacted laws on the storage of toxic chemical control agents.

Storage

What demands must be met by the equipment of a store room for toxic chemical control agents?

The store must be a closed room with walls of solid brickwork or concrete.

The store room must not communicate with inhabited rooms, stables and supply depots. The room must be accessible from the outside by a separate entrance.

The door should carry a safety lock. Take care that locks cannot be removed.

Windows should be barred to prevent entry from the outside and must have shutters which can be closed from inside.

The roof of the store room must be tight to prevent water from entering.

The floor should be seamless so that proper cleaning is possible in case of soiling.

The inside of the room should be clean and orderly.

Poisonous control agents must be stored in their original containers and arranged in a manner easy to overlook. Only implements and utensils for carrying out control treatments may be kept in the store room together with the agents.

A book or file for registering incoming and outgoing goods must be kept so that the size of momentary stocks can be established easily. Responsible authorities must carry out check-ups at certain intervals of time.

When handing out agents the recipient should be instructed on how to handle the issued preparation.

In the store room a board should be displayed carrying the inscription "Beware of poison, smoking and use of fire and open lights prohibited". Carry out running controls of order and security.

D. POISON REGULATIONS GOVERNING THE USE OF CHEMICAL CONTROL AGENTS

All chemical control agents which may cause harm to man and domestic animals when applied, irrespective of their action on pests and diseases, are denoted as "poisons". To avoid health hazards to man and to prevent misuse legal regulations on the trade with and the handling of chemical control agents have been passed by several countries. These regulations classify the agents into certain poison categories according to their degree of toxicity. As a rule they are classified as "very poisonous", "highly poisonous" and "less poisonous" control agents. The various poison categories must be characterized by certain symbols, such as a skull and crossbones or by special directions such as "poison", "caution" or a certain colour of print so that the attention of users is attracted.

The names of the control agents and the producers must be distinctly visible on the container in which the product is sold. It should also carry references pertaining to contents, storage and directions for use.

Easily inflammable chemical control agents should carry the word "inflammable" on the container. If chemical control agents are toxic to bees and fish this also should be recorded. Numerous countries have enacted laws for the protection of bees. Some poisons must be coloured with a warning dye, thus seed disinfectants must contain a dye to prevent them from being mistaken for flour.

In most countries there are regulations on the dispatch of poisonous control agents by post, rail or road transport. The same applies to trading.

The sale of strong and very strong poisons must be entered in poison books. These must be kept for longer periods of time as regulated by the pertinent laws. Before handing over control agents the buyer must first be informed of its properties and potential applications.

E. FIRST AID IN CASES OF POISONING WITH CHEMICAL CONTROL AGENTS

Considering the extremely high production and wide application of synthetic insecticides of various types poisoning with chemical control agents is extremely rare. Causes of poisoning usually are insufficient knowledge of the agent used, inexpert handling and disregard of the directions for use.

Which measures must be adopted first?

In all cases of poisoning a doctor should be called without delay. In the meantime the poisoned person must be removed from the treated area and laid down in a quiet spot.

In cases of dermal poisoning all infected articles of clothing must be removed and the skin washed thoroughly with soap and water.

If the poison has entered the body by way of the mouth an emetic must be applied till the stomach is emptied completely.

Persons poisoned by a respiratory toxicant must be removed to fresh air immediately and artificial respiration carried out if necessary.

Splashes in the eye are removed by rinsing with plenty of water.

Poison symptoms of the chief active ingredients:

Chlorinated hydrocarbons

Symptoms:

Nervous over-excitement, twitching of eyelids, muscle tremour, symptoms of paralysis, head-ache, nausea, vomiting, dizziness.

Treatment:

Gastric lavage with addition of plenty of carbo medicinalis, saline purgatives (15—30 g of sodium sulfate) applied by stomach tube, prophylactic dose of 0,1—0,2 g of Luminal against convulsions; no milk or castor oil in cases of DDT poisoning.

Organic phosphorus compounds

Symptoms:

Poisoning with organic phosphorus compounds or organic phosphates resp. causes indisposition, oppression and head-ache coupled with convulsive muscle contractions on the breast and pupil contraction. There may be additional symptoms such as nausea, vomiting, salivation, diarrhea, muscle convulsions, paralysis of heart activity.

Treatment:

Take 1 mg tablets of atropine. With heavy cyanosis be careful with atropine, apply oxygen and heart stimulants first, set and keep the respiratory tract free by aspirating tracheal and bronchial secretions. In cases of poisoning by peroral administration, carry out stomach lavages with tepid water, preferably 5% sodium bicarbonate solution; rinse eyes with water or physiological sodium chloride solution.

Dinitro-o-cresol

Symptoms:

Mouth and throat corrosion, whitening of the skin, thirst sensation, unrest, perspiration, high fever, dizziness, nausea, vomiting, dropping blood pressure and increasing heart frequency, urine coloured dark green.

Treatment:

Gastric lavage with 5% sodium bicarbonate solution, apply 15—30 g of sodium sulfate with stomach tube, control fever with physical methods, infusion of sodium chloride and glucose solution, oxygen and blood transfusion.

Organic mercury compounds

Symptoms:

Burning feeling in mouth, throat and beneath the breast bone, strong salivation, heavy collapse, dropping blood pressure, increasing pulse frequency, diarrhea, unrest, disordered speech, delirium.

Treatment:

Administer milk and proteins, gastric lavage with 2—5 % sodium bicarbonate solution, apply sodium sulfate with stomach tube.

IX. APPLICATION METHODS AND EQUIPMENT

Distribution of chemical agents for pest, disease and weed control is carried out with plant protection equipment which, by its construction and mode of action, is adapted to a wide range of conditions. Effective control of injurious organisms to-day is impossible without plant protection equipment. Like the chemical agents, control equipment has also been perfected and rendered more efficient. Manufacturers to-day offer a large number of efficient plant protection implements for all agricultural and horticultural cultures and forestry. This trend helped to make work easier, to reduce the number of unskilled workers, to raise productivity and to carry out control measures at the most timely moment. In this way complete economy has been attained.

A. DUSTING AND DUSTERS

(1) Description of the procedure

Application and distribution of pesticide dusts by means of an air blast is called dusting. From a chronological point of view this is the oldest method. It suffers from the drawback that the application of dust is subject to wind influence. Dusting can be carried out during absolute calm only. Some dusts possess low adhesivity and stability to rain. This method is, therefore, less suited for tropical regions with heavy rainfalls. From an economic point of view the costs of dusting are very high. Dust quantities to be applied per hectare range from 10—30 kg.

To improve the adhesivity of agents on foliage a new procedure, da mp dusting, has been introduced. Water is sprayed into the dust stream, thus moistening the dust particles.

(2) Dusters

Knapsack dusters

This type of duster can be carried on the back and works with a continuous airstream produced by single or double acting bellows. The bellows are operated with one hand leaving the other free to handle the discharge tube. The sntermittent discharge of dust prevents the formation of a uniform coating.

Knapsack-type turbo-duster

Of all the knapsack-types of equipment this duster has proved its worth best. With its continuous air stream the dust is distributed better and more uniformly on food plants than with the bellows-type duster.

Knapsack-type engine-powered dusters

Dusters, driven by small motors, have been constructed which may be carried on the back. However, the additional weight and the motor vibrations are a handicap.

Knapsack-type motor dusters designed for two persons are better and more popular. The dusting device is mounted on a portable metal frame. A 2—3 HP gasoline engine drives and regulates the adjustable dust supply. In low or young cultures the appliance is carried like a stretcher, in breast-high cultures, like cotton, coffee or tea, it is carried on the shoulders. These dusters have proved particularly useful in difficult and sloping terrain (fig. 37).

Horse-drawn traction dusters

These are two wheeled, horse-drawn wheel-geared dusters. The hopper is mounted on the chassis together with fan and gear box. The fan is geared to the wheels with chains. This type of equipment is little used nowadays.

Tractor dusters with a single outlet

The fan is driven either by a tractor take-off mechanism or an extra gasoline engine. Dusters of this type can be mounted on a tractor or a trailer. They may be fitted with additional spray devices. The spray liquid, which is fed in centrally, practically without pressure, into the delivery head is divided by the air blast into small droplets. The size of the droplets thus produced and the degree of coverage of the treated area, however, frequently are not very uniform.

Tractor dusters with one discharge nozzle possess a relatively long range. This is particularly desirable when cultures have to be treated at an advanced stage of growth. On the other hand, dust sediments on plants from dusters with a horizontal outlet may be very uneven. In addition, a considerable proportion of dust is carried away by drift. These implements may, therefore, be used for dusting on calm days, at night or in the early morning hours only.

Tractor dusters with multiple outlets

In these machines the ventilator is usually geared to the power take-off and is provided with six or more tangential connecting tubes to which elastic tubes have been fitted. The metal or rubber discharge tubes are drawn along the plant rows by means of a tractor and the dust applied to the plants from above through nozzles.

The nozzles may also be arranged in such a way that the agent is blown on to the plant rows from two sides. In numerous types of equipment the nozzles can be adjusted to row width and plant size.

Fig. 37. Portable engine-powered duster

With multiple outlet dusters less dust is carried away by reigning or rising winds because the agent is distributed from above between the plants which thus protect it from the wind.

With regard to dust consumption this type of equipment is more economical and, above all, can be used for more hours per day than motor dusters with one outlet.

Equipment for damp dusting is on the market already for some years. In addition to the hopper they possess a water tank and are constructed in such

a way that water is sprayed into the emitted dust stream at the nozzle opening. The purpose of this mechanism is to improve the adhesivity of dust which adheres better to wet than to dry foliage.

B. SPRAYING AND SPRAYERS

(1) Description of the procedure

Distribution of liquid control agents with hydraulic comminution in spray nozzles to droplets with a diameter larger than 150 μ (1 $\mu = 0.001$ mm) is called spraying.

Drawbacks of the procedure are the relatively large amounts of water required in field cultures (400—600 litres/hectare) and the transport of large quantities of water. The covered area is relatively small and costs high. Advantages are the possibility of more accurate dosing and better adhesivity of the agents on plants after drying.

(2) Sprayers

This type of equipment to-day is still much in vogue and still of some importance. The pressure-producing pump is either operated by hand or by an engine or geared to the ground wheels.

Knapsack-type diaphragm sprayer

This type of sprayer is equipped with a hand-operated diaphragm pump mounted below the tank and maintaining an operating pressure of 3—4 atmospheres. Owing to its light weight and its constant readiness for use it is still in use in tropical countries with surplus manpower.

Knapsack-type piston sprayer

This sprayer is obsolete because the operator has to work the pump with his left hand and to direct the discharge tube with the other.

A simple piston pump, mounted outside the tank and connected with the spray tank, forces the liquid out of the tank with an operating pressure of 4—6 atmospheres. Being easy to handle, this type of sprayer is still in use to-day.

Knapsack-type compression sprayer

A piston pump which drives the liquid out with a pressure of 5 atmospheres is fitted in an air-tight knapsack-type tank. The pressure drops relatively quickly so that frequent pumping is necessary. The sprayer is provided with a manometer and a safety valve which allows the air to escape when the pressure is excessive.

This type of sprayer is still widely used in practice.

Knapsack-type high pressure sprayer

A feed and force pump maintains a pressure of 3 atmospheres within the sprayer rising to 10 atmospheres each time spray liquid is pumped in. A ball-type valve prevents the escape of the compressed air, the ball settling on the valve shortly before the tank is completely empty. This never relaxing excess pressure permits careful work and longer distribution ranges. It is a useful piece of equipment for small plantations. It is also being used in field cultures, particularly when small areas of infection or infestation have to be treated or where tractor sprayers cannot penetrate to.

Cart sprayer

This sprayer is mounted on a one- or two-wheeled cart and operated by two men. The spray tank has a capacity of 50—100 litres. The hand-operated piston pump may be mounted inside or on top of the tank. It produces an operating pressure of 12—15 atmospheres. This easily operated piece of equipment is still in use in small plantations.

Traction field sprayer

When this two-wheeled, easily operated sprayer is drawn by horses or a tractor the propelling force is transmitted from one or both ground wheels and drives the pump. It has an operating pressure of 3—8 atmospheres. The water tank has a capacity of 200—300 litres and is mounted at right angles to the direction of motion.

The distribution range of this sprayer is 5—10 metres. The track width is adjustable. The sprayer is still in use in field cultures.

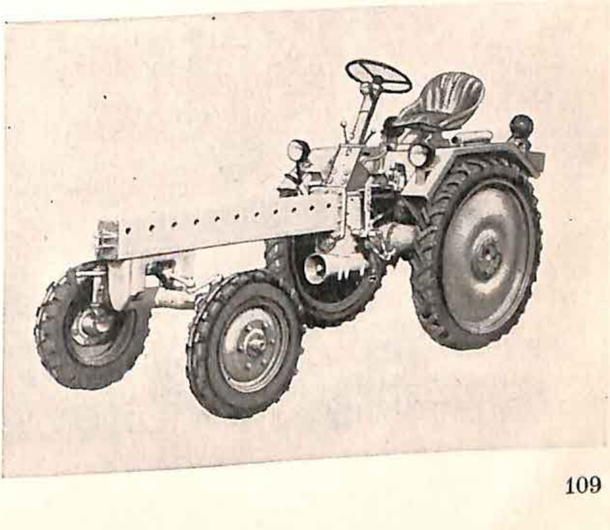


Fig. 38
Implement carrier

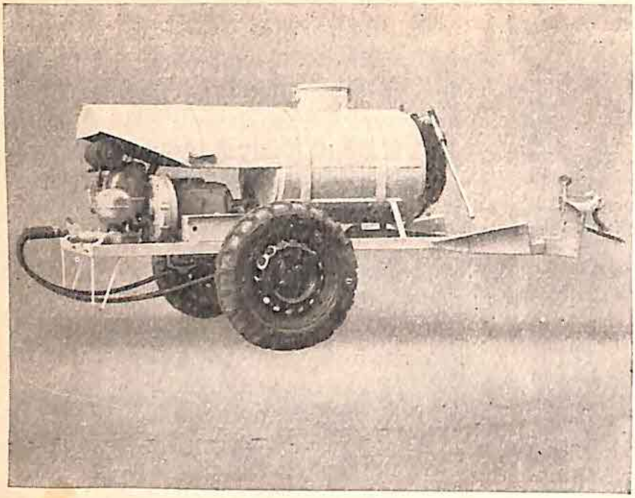


Fig. 39. Engine-powered sprayer

Engine-powered sprayers

This type of sprayer has an incomparably larger output capacity. Usually it is driven by or mounted on tractors, special implement carriers also being suitable for the second purpose (fig. 38, 39).

The pump is driven either directly by an engine or geared to the power take-off so that pump and agitator are driven by the tractor drive shaft. Equipment for high-pressure spraying usually is provided with a three cylinder piston pump and an automatic pressure regulator. Of late, rotary pumps have been introduced for the purpose. Plunger pumps are rarely used in this type of equipment.

The spray tank has a capacity of 200—1,000 litres. Operating pressure ranges from 10—50 atmospheres and the delivery per minute amounts to 20—70 litres (figs. 40, 41).

For high-grown field cultures (cotton, maize, tobacco) or young cocoa, coffee, tea, citrus and banana plantations special sprayers with high ground-clearance of 1.50 metres or more have been constructed.

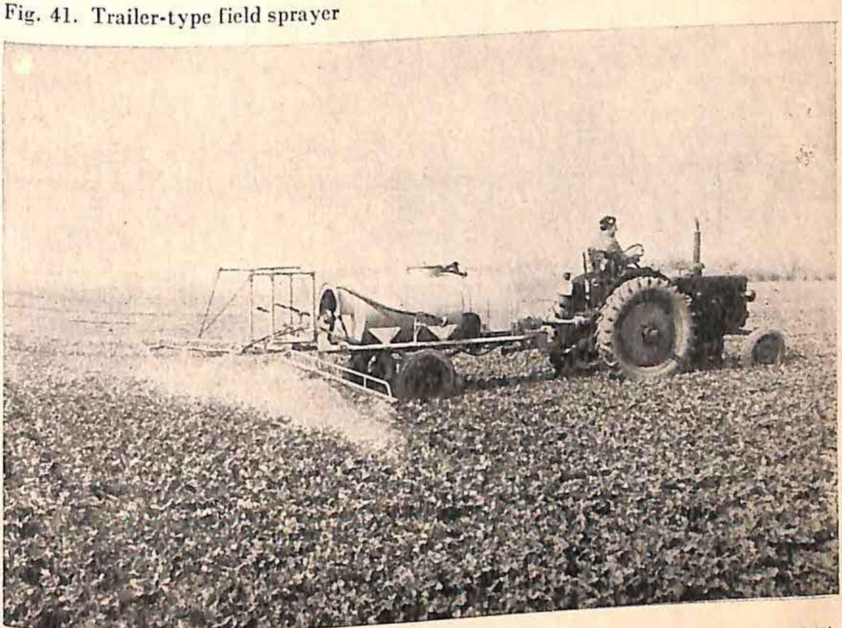
C. ATOMIZING AND ATOMIZERS

(1) Description of the procedure

Distribution of liquid chemical control agents in droplets, 50—150 μ in diameter, is called atomizing. It is carried out either pneumatically by means of an air stream produced by a ventilator or compressor or in a combined hydraulic-pneumatic way.

Fig. 40. Spray implement for chemical weed control

Fig. 41. Trailer-type field sprayer



The airstream at the same time serves as a carrier of the liquid particles. It is so strong that the leaves are agitated, thus ensuring all-round coverage.

The water quantities are reduced to 10—20 % of those needed for spraying. There is, however, no saving of spray agent. Regardless of the procedure adopted – spraying or atomizing – the plants must always get the same quantity of agent. For atomizing, therefore, the concentration of the spray liquid must be 5—10 times higher.

Advantages of atomizing: shorter time to render the equipment ready for use since frequent refilling can be dispensed with and, consequently, higher implement efficiency, high area coverage and timely treatment within short periods of time. This is particularly important for control of fungous diseases which, to be successful, must be carried out within the shortest possible time after infection. Furthermore, with atomizing a more uniform and well-adhering agent coating can be obtained.

A large number of factors must be considered when atomizing. The plant protectant must meet certain demands. With the high concentrations employed only such agents may be used which can be distributed as emulsions or suspensions. Suspensions must possess a high suspension ratio. Only agents with a high content of active ingredient and low application strength may be employed. High concentration agents tend to form thick liquids which are difficult to apply. Overdosages must be avoided under all circumstances lest the plants suffer phytotoxic damages. In warm countries volatile control agents should be atomized during cool evening or night hours only. In the day-time heat, part of the agent would evaporate before the droplets contact the leaves.

(2) Atomizers

In this type of equipment the liquid is fed by slight pressure or vacuum into an air blast, generated by a blower, which breaks it into fine droplets and directs them onto the plants. This became possible after the construction of a low volume nozzle. The quantity of spray liquid per hectare is reduced for insecticides in field cultures to 50—200 litres and in fruit-growing to 200 to 600 litres, the corresponding figures for the normal spraying procedure being 600—1,000 and 1,500—3,000 resp. The application rate for growth regulator-type herbicides also amounts to 200 litres per hectare but for contact herbicides it should not be less than 600 litres per hectare. Atomizing has gained significance in all tropical and subtropical cultures and the equipment industry developed numerous atomizers for this purpose. Besides knapsack-type engine-powered atomizers, which have proved useful in cultures on steep or inaccessible terrain, manifold types of tractor atomizers have been constructed which can be mounted on tractors or trailers.

Special mention must be made of one-man-operated, self-propelled atomizers. With such machines a cotton field, a pine apple, citrus or coffee plantation can be treated within a very short time (fig. 42).

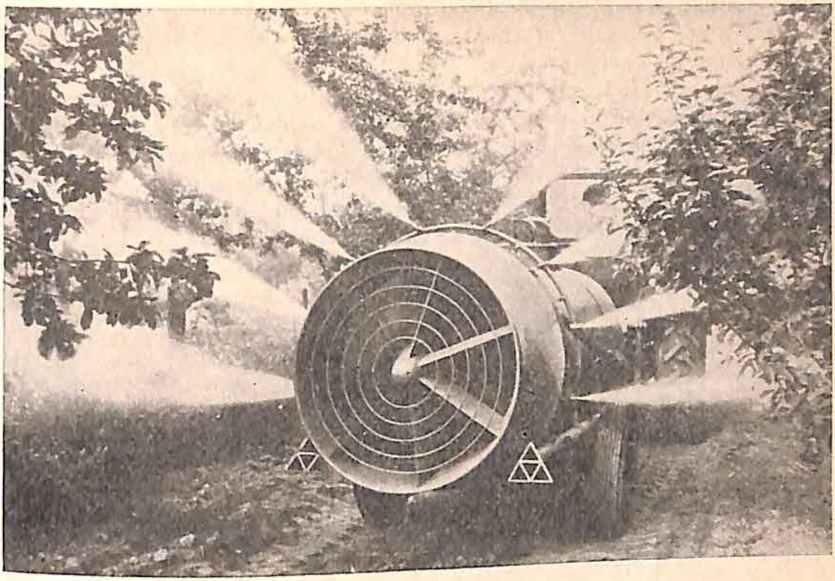


Fig. 42. Large-volume sprayer

Fig. 43. Tractor-mounted sprayer and duster

Some atomizers are equipped with spray nozzles which can be mechanically adjusted by the driver when spraying so that differing heights of cultures can be taken into account.

The equipment industry has constructed multiple-purpose equipment for all types of application methods mentioned above. Thus there exist knapsack-type and mobile engine-powered dusters and atomizers and combined dusting, spraying and atomizing equipment. The mobile implements may be mounted on or drawn by tractors. These multiple-purpose implements assert themselves to an ever increasing extent (figs. 43 to 45).

D. FOG PRODUCTION AND FOG MACHINES

(1) Description of the procedure

Production and distribution of droplets less than 50 μ in diameter is termed fogging. Such fogs are also termed aerosols. They can be produced by application of heat or mechanically. In the first type of procedure warm or hot fogs are produced by heating liquid agents to such an extent that they evaporate for a short time and then re-condense in the cool out-door atmosphere to form very fine droplets (fogs).

Fig. 44. Tractor-mounted sprayer and duster

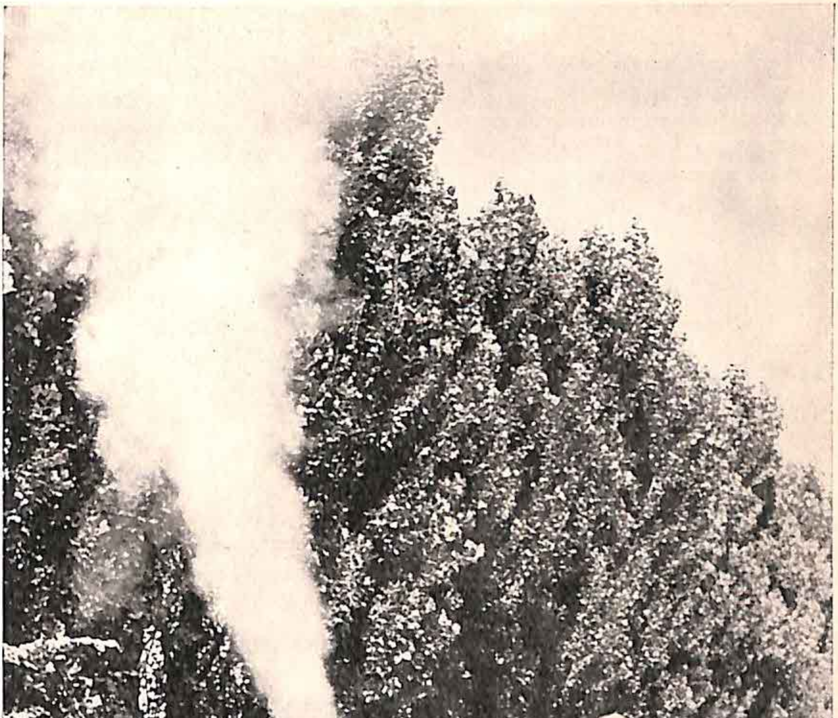


Fig. 45. Tractor-mounted sprayer and duster

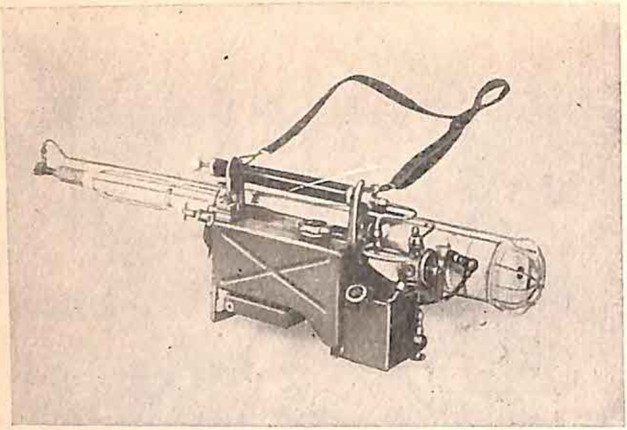
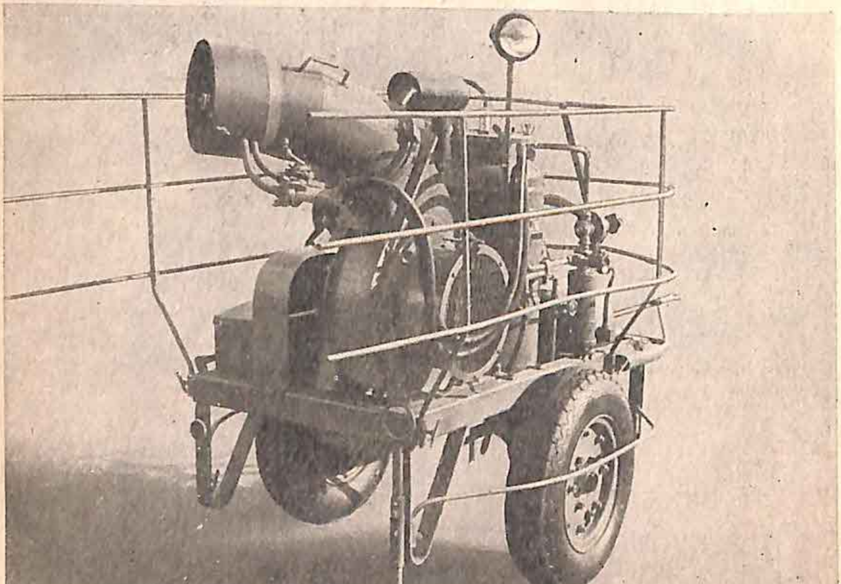


Fig. 46. Knapsack-type fog machine

Mechanical (cold) fogs are produced by atomizing the agents with compressed air to which a whirling motion has been imparted in special nozzles. The drop-

Fig. 47. Trailer-type fog machine



lets produced in this manner are generally somewhat larger than those in condensation (warm) fogs.

Fogs often are sub-divided further into dry fogs, with droplets smaller than 15 μ, and wet fogs, with droplets larger than 15 μ. The range of distribution of wet fog is somewhat shorter than that of dry fog. The droplets of wet fogs fall to the ground sooner.

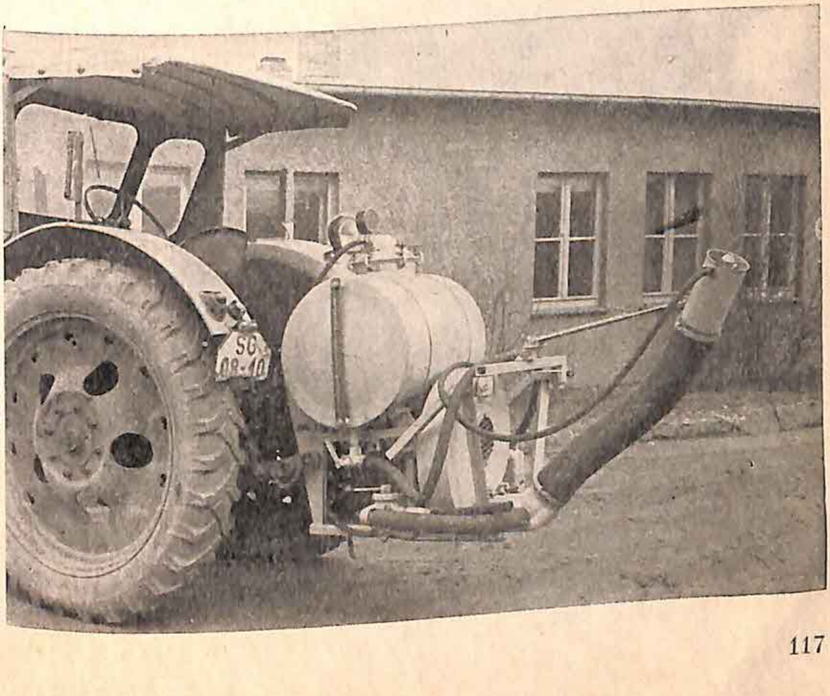
(2) Fog machines

We distinguish warm and cold fog generators, sometimes also called condensation and dispersion fog machines. Both stationary and portable types have been constructed, the latter being designed to be carried by a man or to be mounted on a tractor or trailer (fig. 46 to 48).

Fog machines are very economical in operation. No spray liquid has to be made up. The area covered per hour is very large. This is particularly valuable for concerted control of injurious insects in the event of a sudden outbreak or infestation of large areas.

They are also well suited for use in forestry and in inaccessible terrain. The lower application rates of 3—10 litres fog agent/hectare are noteworthy. Fogs possess good adhesivity and remain active for lengthy periods of time.

Fig. 48. Tractor-mounted fog machine



A draw-back of the procedure is its dependence on air movement and thermal air currents.

They are well suited for application in the open, especially for controlling biting insects in forest, plantation and field cultures. The procedure is particularly valuable for combating disease carriers in disease-ridden areas such as gnats *(Culicidae)*, sand flies *(Simuliidae* and *Phlebotomus species)*, horse flies *(Tabanidae)*, house and stable flies *(Muscidae* and Stomoxidae*)* and tsetse flies *(Glossininae)* etc. (Fig. 49).

Fog generators may also be used for indoor-treatment, particularly for controlling stored product pests and disease vectors.

E. APPLICATION BY AIRCRAFT

Throughout the world aircraft, such as one-engined low- and high-winged monoplanes, biplanes and helicopters, are being used to an ever increasing extent for many plant protection purposes. The number of planes employed is quite considerable. They are used for pest and weed control, distribution of mineral fertilizers and sowing. Large-scale cultivation of useful plants, shortage of

Fig. 49. Fog machine combating gnats in Kumasi (Ghana)

labour, technization and rationalization have led to an increasing use of aircraft in agriculture, forestry and fruit-growing.

According to 1961 statistics the following areas of cultivation, in hectares, have been treated from the air to control pests and diseases.

USA	27,000,000	Mexico	439,000
Soviet Union	25,000,000	Spain	300,000
Sudan	480,000	Iran	280,000
France	450.000	German Democratic Republic	258,000

The advantages offered by the use of aircraft are obvious. Less manpower is needed per hectare. The transport of water can be dispensed with. Tractive vehicles can be employed for other purposes. The area coverage of aircraft is larger. It is thus possible to treat large areas at the biologically most favourable date within a few hours. When using aircraft the state of the soil, plant size and – in rice cultivation – the numerous irrigation canals can be disregarded. Soil compressions are avoided altogether and plants remain unharmed. All these are factors which no longer permit the use of ground machines.

During the last few years helicopters have been employed to an ever increasing extent. This is due to the obvious merits of this type of aircraft. A helicopter is not bound to an airfield, being able to take off and to land in the immediate vicinity of the areas to be treated. Being able to vary its velocity from 0 to 150 km/h it is in a position to fly sideways, backwards and vertically upwards or to hover on the spot. Hence it can adapt itself excellently to terrain and plantation conditions and also permits treatment of small areas during large-scale control actions (fig. 50).

Helicopters can be fitted with manifold types of accessory equipment such as dusters, sprayers and cold fog generators, thus permitting the distribution of all dust and spray agents employed in plant protection at the present time.

It has been found that the use of aircraft is economical and in most cases costs roughly equal those of control actions with ground machines. In those instances where this is not true the indubitable advantages balance the higher costs.

(1) Aircraft application procedures

(a) Aircraft dusting

For aircraft dusting the pump and discharge tubes are replaced by a dusting fan fitted below the fuselage within the propeller stream. The hopper contains an agitator for dusting driven by the aircraft engine and is usually situated at the back of the pilot seat.

To prevent the dust from drifting away the aircraft should fly at a height of 1—3 meters above the plants. This assures a uniform deposit of dust on all plant parts.

Fig. 50. Aircraft carrying out control treatment

The downward movement of the dust is furthered by the downblast and the vortices produced by the wings.

The downblast and vortices produced by high-winged planes within plant cultivations are weaker than those of biplanes or low-winged monoplanes. For this reason low-winged planes are best suited for distributing dust. These vortices (turbulence) on the one hand influence the breadth of the dust swath and on the other, when flying at optimum height, help the dust to contact not only the bottom leaves but even part of the lower surfaces of the plant leaves. When dusting dew-moist plants the dust adheres particularly well.

The rate of settling of the dust particles is so minimal that dusting by aircraft should be carried out in calm weather only.

Thermal upwinds, which prevent the dust from settling sufficiently, are a serious nuisance. They occur when, due to sun irradiation, the soil grows warmer than the supernatant air layer. The thermal currents carry the dust upward. Aircraft dusting cannot be proceeded with under these circumstances. In view of the weather susceptibility of dusts aircraft dusting is restricted to the cooler morning and evening hours.

(b) Aircraft spraying

The construction of aircraft equipment is in principle the same as that of motorized field sprayers. The spraying device consists of a tank, a pump with

pressure regulator and cut-off and a nozzle tube. The spray equipment is interchangeable with a duster.

The tank, a stainless container, is located at the centre of gravity of the plane. It may be situated in front or at the back of the pilot seat. Its capacity ranges from 200—1,000 litres, depending on the HP of the engine. Usually the pump is driven by a small wind-driven propeller mounted close to the body of the aircraft. In some instances it is situated behind the motor and geared to it or to separate hydraulic engines by means of a shaft. In most cases geared or centrifugal pumps, driven by the aircraft engine, are employed.

Special nozzles have been constructed for aircraft spraying. Unlike nozzles of ground machines they possess a valve which shuts automatically when pump pressure drops below a certain adjustable level. This is achieved by means of a membrane, subjected to the pressure of a spring, which, at higher pressures, is pushed aside by the liquid, thereby giving access to a tube leading into the open. Nozzles of this type of construction not only shut automatically but also do not drip after shutting.

The droplets leaving the nozzle orifice are atomized yet further by the air blast produced by the speed of the plane, which amounts to 120—150 km/h. To obtain minimum size droplets the nozzles are not directed backwards but slightly sloping downwards or forward, the difference of velocity between droplets and airblast and, consequently, the degree of comminution being greater this way. The nozzles are mounted below the wings.

Fig. 51. Helicopter spraying apparatus

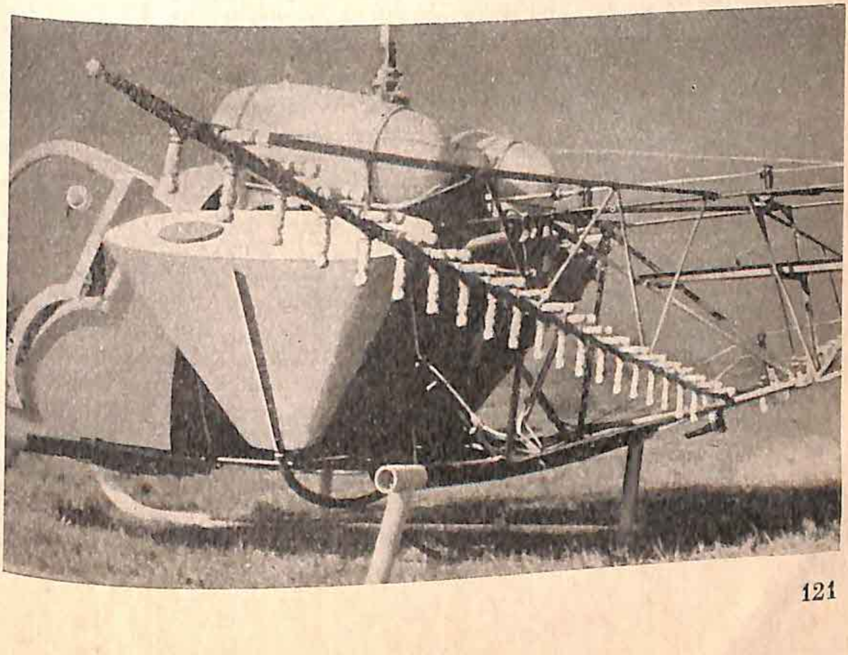


Fig. 52 Helicopter carrying out control treatment

In helicopters the nozzles are situated in front of the cockpit. The droplets are driven down into the plant cultures by the downblast of the rotary blades. The tanks are on the left and right beneath the rotor (figs. 51, 52).

Helicopters produce a swath 10—30 meters wide.

When using aircraft the success of control measures depends to a large extent on the uniformity with which a certain quantity of agent is deposited on the cultures. Theoretically, this will be the easier the more spray liquid or dust is split up into small droplets or particles. Aircraft nozzles, however, must produce droplets with a larger diameter than nozzles in ground machinery, because the path from orifice to plant is longer. The exposure to drift and evaporation is greater. Warm and dry air promotes evaporation. When spraying from aircraft in tropical regions with an air humidity of 90 % or more, it is possible to work with smaller droplet sizes.

(2) Organization of aircraft treatment

An aircraft is a highly efficient instrument at the disposal of plant protection. Full use of this capacity can, however, be made only if the entire procedure is organized properly right from the start, including all precautionary measures with respect to the agent.

Matters to be organized include the timely transport of the necessary agents and diluents, such as water, provision of aircraft loading and filling equipment,

water and fuel transport vehicles and mixing tanks fitted, if possible, with an agitator (for suspensions) so that all are at hand and ready for use. There also must be a sufficient number of auxiliary workers.

Greatest attention must be paid to the drawing up of orientation charts. The latest edition of 1:5,000 to 1:25,000 scale maps should be used for this purpose and the area to be flown over marked on them. The areas to be treated must also be entered accurately and their size – in hectares – noted. Length and breadth are entered in metres. The plots to be treated must be numbered and entered in a list. Dangerous high-voltage lines, hedges, solitary trees and other points of danger exceeding a height of 5 meters on or within 2,000 meters of the areas to be treated and the landing ground must also be entered in the chart.

Another major factor for expert work is the signal system to mark the direction of flight. The signals may be stationary or mobile. When flying over areas larger than 20 hectares 2—4 signal men are necessary. If the cultures consist of well-discernible row crops or if there are other prominent landmarks the flagmen can be dispensed with. In all other instances the areas must be marked in such a manner that the pilot may recognize them easily.

Air approach to the areas to be treated must be unhindered in at least two directions. The areas should not be smaller than 15 hectares when using rigid-winged aircraft and not less than 3—5 hectares for helicopters.

The auxiliary air field for rigid-winged planes should be on a plot with hard soil 400—600 meters long and 100—300 meters wide, acc. to the type of aircraft employed. For helicopters a landing ground of 25 × 25 meters and a landing site of 5 × 5 meters suffice. The take-off and landing vista must be free of obstacles and protected. The auxiliary airfield is off-limits except for authorized persons and must be roped off.

For economic reasons the distance between landing ground and the area to be treated should not exceed 5 kilometres for rigid-winged aircraft and 1 kilometre for helicopters.

Before the control action is started the public in the areas concerned must be informed by the press and through official notices. The police must also be notified.

The time of work for the aircraft should be from sunrise to 10 a.m. and in the evenings from 5 p.m. to sunset, wind and temperature conditions being most favourable during these periods.

Work must stop when wind velocities exceed 3—5 meters/sec. Before, during or after rain and when temperatures rise above 25 °C. no flights should be undertaken.

F. NOZZLE TYPES

The discharge tube with the nozzles may be regarded as the most important part of a sprayer. Only flawless sets of nozzles guarantee uniform distribution of spray liquid. It depends upon their adjustment whether the plants are wetted sufficiently by the spray droplets. Nozzles must tally with regard to type, width of boring, type of whirl and baffle plate distance. Differences in nozzle bore give an irregular spray pattern leading to damages in cultures or unsatisfactory action of the control agent. When all nozzles are of the same type and act in conjunction a uniform spray pattern is obtained along the entire breadth of the spray swath.

In this connection the soiling of nozzles with dirt must not be left unmentioned. During spraying the nozzles must be inspected constantly and deviations from normal spray capacity precluded. Soiling may be due to unclean water, rusty parts and old residues of spray liquid in the tank. The strainers between tank and discharge tube and in the nozzles must be inspected and cleaned regularly.

When the water used for diluting is poured or pumped into the tank it must first be passed through a strainer. Nozzles function properly only when there is a uniform and satisfactory pressure of liquid. Pressure variations may be caused by leaks in the discharge tube, the pipes or at the nozzle head.

To obtain a uniform spray pattern the optimum distance between nozzle and culture must be observed exactly. Maintainance of the requisite driving speed and pressure is a prerequisite for this.

When selecting the type of nozzle the following points must be considered:

Cultivated plants

The denser and larger the leaf mass of the cultivated plant the more difficult it is to wet the leaves in the centre.

Due to the air current originating at the nozzles during spraying, fine droplets penetrate plant cultures better than bigger ones. For good penetration it is important to point the nozzles at the plants correctly.

Pests

With caterpillars, weevils and other very mobile injurious insects droplet size is not such a decisive factor since the pests contact the pesticide coating when moving about. In the case of plant lice and spider mites, which move relatively little, small droplets and very uniform distribution are important because as many pests as possible must be brought into contact with the agent.

Other conditions obtain for the application of systemic preparations which are absorbed by the plants.

Nozzles are sub-divided into spray nozzles and

atomizing nozzles (fig. 53).

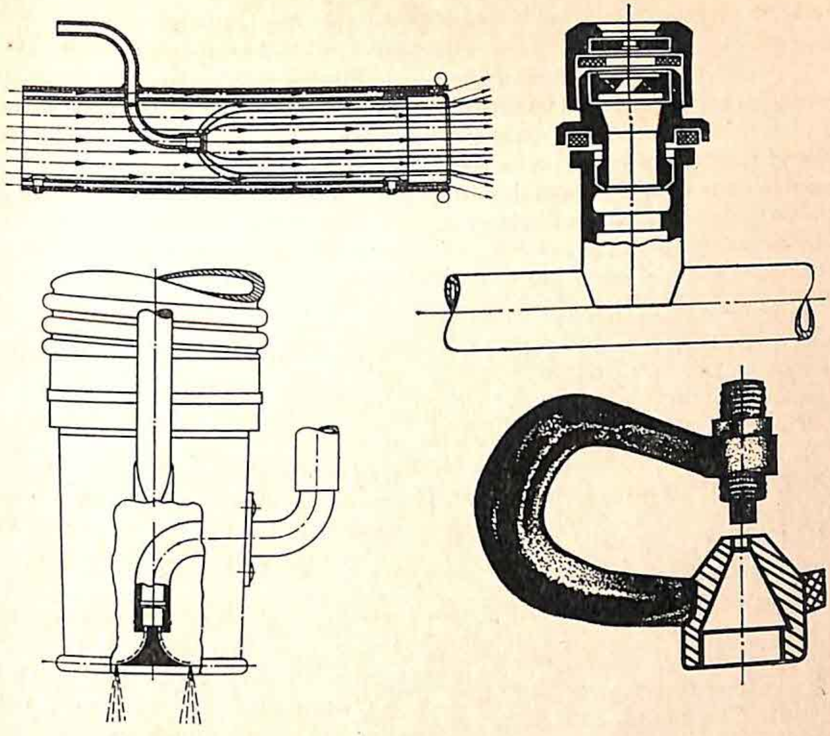


Fig. 53. Various nozzle types

Spray nozzles

In these nozzles the liquid is broken up into droplets hydraulically. For field spraying, baffle nozzles, also called flat spray nozzles, are employed. Baffle nozzles produce a fan-shaped spray. They are arranged on the discharge tube in such a way that the fans overlap. To obtain uniform distribution the tube must be adjusted during the spraying operation in such a way that the spray mists meet a short distance above the plant tops.

The spray liquid leaving the nozzle boring impinges upon a baffle plate with a slit. Nozzle boring and baffle plate must be arranged exactly opposite each other and a fixed distance apart. The liquid passes downward through the baffle plate slit and emerges as a compact fan which is then disintegrated into small droplets by the resistance of the atmospheric air. There are nozzles of various sizes with different borings. The wider the boring the larger is the quantity discharged per minute.

In baffle nozzles producing a cone-shaped spray, a rotating motion is imparted to the spray liquid by a whirl with thread-like borings placed in front of a nozzle disc. After passage of the nozzle disc opening a cone-shaped film is produced which is broken up into droplets. The whirl mechanism may also be a plate with excentrically arranged holes bored at an angle. To increase discharge rates the discs are perforated in the centre. Baffle nozzles, too, are supplied in various sizes with nozzle borings of different widths. The wider the boring the larger is the quantity discharged.

Atomizing nozzles

In atomizing nozzles the spray liquid is atomized pneumatically, that is with an air blast or in a combined hydraulic-pneumatic way, wherein the liquid is first broken up hydraulically by means of baffle nozzles and then further comminuted into small droplets by an airblast generated by a blower.

There are several types of atomizing nozzles:

In mushroom nozzles a mushroom-shaped baffle plate with sharp edges is situated in the centre of the air blast. The spray liquid emerges sideways below the plate through 4—6 holes. It is then pressed against the baffle plate by the air blast and atomized at the sharp edges to small droplets. The air blast carries the droplets to the plants.

Double mantle nozzles consist of two concentric cylinders, termed inner and outer mantle. The spray liquid is fed to the centre of the inner mantle and sprayed with a jet on to the inner wall of the inner mantle. The air blast drives it as a thin film to the edge of the inner mantle, which is provided with numerous small borings. The fine droplets forming at the edge and borings mingle with the inner airblast. An extra air current emerges between the two mantles which helps to compact the air-droplet mixture so that it will carry a greater distance.

In yet another type of nozzle the spray liquid is atomized hydraulically in a baffle nozzle by an air blast produced by a blower, the spray liquid and air blast having the same direction.

In counter current nozzles the baffle nozzle is directed against the direction of movement of the air blast. The spray liquid is thus sprayed against the air blast, a higher degree of atomization being obtained in this way.

For cold fog machines, too, special atomizing nozzles, adjusted to very low rates of discharge, have been developed. Compressed air and the fog agent are introduced separately. Depending upon the type of fog machine the fog agent is either sucked up into the jet by the emitting compressed air or introduced under pressure.

G. SEED DISINFECTION EQUIPMENT

Treatment of seeds against seed-borne disease pathogens is one of the most effective and uncomplicated and – costs being low – economical measures of plant protection.

The question whether dust or liquid seed treatment methods should be preferred can be answered by saying that no differences in effectiveness between both methods have been established.

Dust treatment, however, is more convenient and is carried out quickly. It has gained ground more and more on the liquid treatment procedure.

Barrel seed treaters

This uncomplicated type of equipment is nowadays being used in few small agricultural establishments only. It consists of a hand- or engine-driven cylindrical, obtuse conical or spherical drum which can be rotated along its longitudinal and lateral axes and is fitted inside with mixing boards. Rotation must be slow (approx. 40 revolutions per minute) or the seeds will be pressed against the wall by centrifugal forces and treatment would not be uniform.

A known quantity of seed is placed in the drum and the requisite amount of dust added. After sealing, the drum is rotated for 3—5 minutes. The capacity of these treaters is low.

Dust seed treaters

These are engine-powered machines consisting of a continuously working mixing drum with an outlet and a contrivance for the seed disinfectant.

The machine may be coupled with a seed cleaning machine so that cleaning and treating can be carried out in one operation.

In early types of this machine the addition of seed disinfectant was regulated by hand. This was extremely inaccurate so that seeds frequently were over- or undertreated. To-day all dust seed treaters are equipped with automatic metering devices. Control appliances or checks are no longer necessary. When treatment begins, the operator, with a simple manipulation, adjusts the dosage to the type of seed to be treated and then can turn to other work. The automatic metering device guarantees automatic adjustment of the inflow of seed or dust.

The machine is fed by means of an elevator. From the discharge end of the elevator the seed is fed to automatic double weighing dump pans and continuously weighed off in fixed quantities. The seed balance is coupled with the seed disinfectant balance which automatically adds the disinfectant. After pre-mixing, seed and disinfectant are fed into a mixing drum which may be arranged in a nearly horizontal position or sloping upwards. There should be 42 drum revolutions per minute. The treated seeds run from the drum to the bagging chamber. Despite the automatic contrivances the treater should be kept under supervision and the working of the metering device checked at intervals (fig. 54).

Moist seed treaters

But for the metering device, which, of course, must be of an entirely different construction, this type of treater closely resembles in its construction the above-mentioned dust treaters.

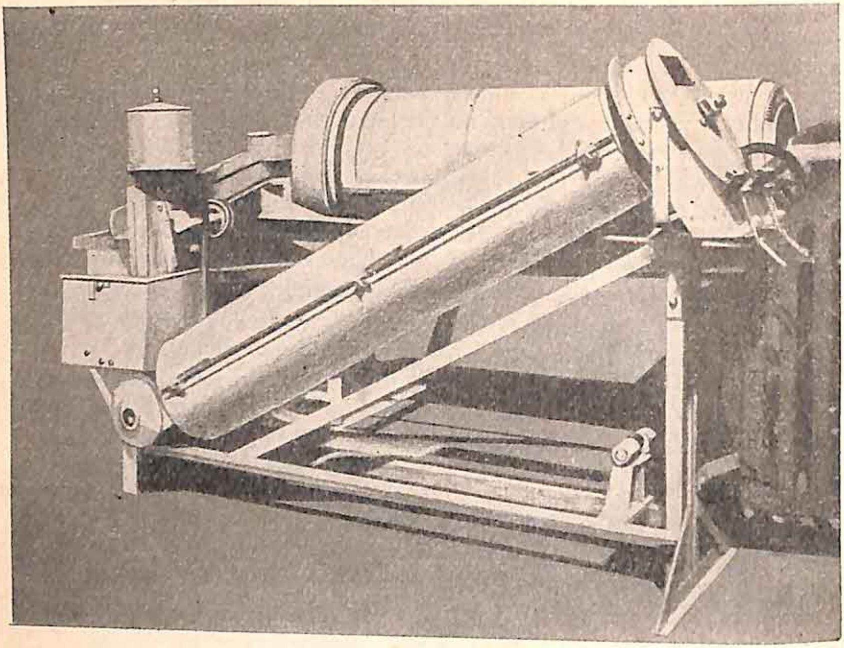


Fig. 54. Seed treater

The metering device consists of an accurately calibrated pair of cups with small vents which is rigidly connected with a seed dump pan. The cups alternately dip into a tank containing seed disinfectant solution. When one of the cups is being filled the other discharges its contents into a funnel. Thence the liquid runs through a pipe into the mixing drum where it is sprinkled on to the seeds, or atomized by means of a jet or rotating disc. This assures highly uniform distribution. Transport of the liquid from the tank may also be effected with a geared or centrifugal pump.

Accessory equipment

Though dust treaters are constructed to be dust-tight it cannot be quite avoided that some dust develops in the vicinity of a continuously working machine. The place where large dust accumulation is yet possible is the bagging device. In large halls this is of no great consequence. In closed rooms, however, with insufficient ventilation, the ground is dyed by the seed disinfectant dust and the dust becomes noxious, so that it may prove necessary to work with a respiratory mask. The dust, however, does not consist solely of seed disinfectant but chiefly contains finely abrased husk particles and dust from the seeds themselves, coloured with seed disinfectant.

Producers of seed treaters have, therefore, constructed exhausters which prevent the escape of dust from the machine or during bagging. This is effected by means of an air current which produces a slight vacuum in the machine. The dust-polluted air is passed through a multi-layer filter and purified. In another type of dust-removing device the seeds, having passed two thirds of the mixing drum and being well coated with disinfectant dust, are automatically moistened with water to bind the dust which partly evaporates again soon afterwards.

These accessories can be installed in dust seed treaters at low cost.

H. MAINTENANCE AND UPKEEP OF PLANT PROTECTION EQUIPMENT AND LABOUR PROTECTION

Chemical control agents are indispensable assistants in the struggle against animal and vegetable pests. Effective application is possible only if the application equipment is always kept in good condition and ready for use at any time. Good maintenance is not only a prerequisite for high efficiency but also for long life of the implements.

After purchasing plant protection equipment and before putting it to service for the first time the enclosed directions for use must first be studied thoroughly and always strictly adhered to. These directions are based on experiences gathered during the course of several years. As a matter of principle one should ask a representative technician of the manufacturers to explain the construction and handling of the equipment and how to dismantle and re-assemble it. The first practical operation should, if possible, take place in the presence of an expert who should give advice on the most frequent types of defects and how to remove them.

The following maintenance and upkeep measures must be carried out:

If the equipment is used every day, oil all bearings according to the lubrication plan included in the directions for use, using recommended lubricants only.

Control regularly the oil level in the gear boxes.

Inspect all V-belts every day and tighten them, if necessary. Heavily strained screw connections must be inspected regularly to see whether they fit tightly.

Control air pressure of trailers every day.

All parts exposed to wear and tear such as valves, ventilator parts, pistons of three cylinder piston pumps etc. must be looked after once in 2—3 weeks and replaced, if necessary.

When preparing control treatments:

The made-up and well-stirred spray liquid must be sifted into the tank. The same applies to the water.

Dusters should be filled with the dust agent on the site of application, not before. This prevents troublesome clotting and setting of the agent. A sufficient number of rapidly wearing parts such as packings, nozzles, valves, valve seats, pistons, hoses etc. must always be at hand during work. Sieves must be looked after and cleaned frequently.

When changing agents clean the equipment thoroughly. This is particularly important after using hormone-type herbicides. In this case all parts of the equipment, not only tank and hoses but even all exterior parts, must be cleaned. Add charcoal (100 g/100 litres) when rinsing and pumping out with water.

At the conclusion of the period of treatment:

After use, clean all implements with hot water containing a cleaning agent and rinse well with clean water.

Dismantle and clean all equipment parts tending to get soiled and polish all bare metal parts with machine oil.

Hardened spray liquid residues, which tend to adhere to the walls should be removed from metal tanks with a chip of wood. The same applies to dust crusts in dusters. Metal tools may cause very fine cracks. This is important for containers subjected to pressure.

Pressure and suction valves must be removed and cleaned thoroughly. Inspect state of valve seats in particular, and replace, if necessary. All safety devices must be checked, safety valves of pressure containers in particular. Be careful when releasing the compressed air. Hoses should be disconnected and hung up unkinked.

Filters and sieves in suction pipes of pumps and on tanks must be cleaned thoroughly.

Free defect spots of rust. Inspect spray liquid tanks in particular, and give them a fresh protective coat of paint, if necessary.

Equipment or individual parts should be sent to the repair shop in time.

Parking of equipment

Equipment should be parked in dry sheds free of draught. Good storage not only extends the life of the equipment but also helps to avoid accidents.

Rubber-tyred plant protection equipment should be laid up to protect the tyres.

The equipment shed must be kept clean and tidy.

If the necessary care for the maintenance of plant protection equipment is always exercised, it will keep for many years. Unnecessary costs are saved and time-robbing defects and troubles avoided.

Directions for labour safety

The manufacturers provide all plant protection equipment with the necessary safety and protective devices so that sources of danger are eliminated to a great extent.

To avoid accidents, the owner, too, is obliged to behave in such a way that accidents are excluded. It does not suffice to observe the labour safety regulations, the equipment, in addition, must not be altered in any way which would reduce or abolish the protective function of a device. When working with plant protection equipment take note of the following: Safety and protective devices must not be removed during operation except during repairs.

Do not work without or with a defect cardan shaft protective device covering the cardan shaft leading from the tractor to the machine. The number of transported persons should not exceed the number of seats provided.

Do not mount or alight from moving machines. Machines without seats or operation stand must not be entered when driving.

Control seat fastenings every day.

Repairs may be carried out on immobilized machines only.

Do not exceed the maximum speed limit.

Illuminate equipment standing in streets and footways in the dark.

X. ECONOMY OF CHEMICAL PLANT PROTECTION MEASURES

Application of plant protection measures entails certain costs both to individual enterprises and to national economy. These consist of the costs for implements, plant protection products and wages. They differ with the area to be treated. The costs for machines must be met but once, but costs of plant protection products vary with supply. Plant protection measures will always be profitable where a shortage of manpower for cultivation measures obtains.

Before every planned plant protection measure it is necessary to calculate roughly the costs accruing to the enterprise. If plant protection measures promise success from the first a rough calculation shows which measure is most economical or which agent will be most effective. Reliable data for calculations is obtained from experiments extending over several years. The degree of infection or infestation in any year is the most inaccurate position in the calculation of possible damages.

The decision on the procedure to be adopted is also governed by the expected value of the crop. A plant protection measure in valuable crop products is more profitable and necessary than in less valuable products. It must also be borne in mind that the decisive factor often is not the extra crop yield alone but the financial profits accruing from better quality obtained by plant protection measures (fruit growing).

Many examples of successful plant protection measures have been reported. The damage caused to coffee crops by the coffee berry borer *(Stephanoderes hampei Ferr.)* has been reduced from 90 % to 5 % by the appropriate application of plant protection measures. The cultivation of bananas in Jamaica, once seriously threatened by the banana leaf spot disease *(Mycosphaerella musicola Leach.)*, has been saved by adopting effective plant protection measures.

Appropriate plant protection measures
- guarantee higher crop yields and crop value,
- secure crop cultivation (regular yields, prevention of crop failures),
- maintain profitableness of crop growing,
- prevent introduction of new pests.

Economic management of agriculture is of decisive importance for the entire national economy. Appropriate plant protection measures prevent

heavy yield fluctuations and, consequently, price fluctuations. Hence plant protection measures must be carried out even when appearing to be unprofitable for individual enterprises when they are of great importance to the national economy. Prevention of damages by means of plant protection measures practically guarantees larger cultivated areas, helps to reduce labour expenditure for unit quantities of harvested crops and facilitates a rise in the quality of agricultural supplies.

XI. EXPLANATION OF TECHNICAL TERMS

A necessary prerequisite for a full understanding of plant protection measures and agents is the knowledge of certain terms pertaining to these subjects. The use of special expressions, abbreviations etc. cannot be quite avoided. Practicians must try to acquire a certain knowledge of some of the more important terms. A collection of such terms, together with the necessary explanations, is presented below.

acaricide	mite-killing agent
active agent or ingredient	active chemical constituent of plant protection product
acute effect	immediate effect
acute toxicity	poison effect after a single application
adhesive	substance which, upon addition to plant protection agent, prolongs adherence of same to the treated area
aerosol	tiny particles of solid or liquid active agent finely dispersed in air
amino acids	organic constituents of proteins
aphicide	aphid-killing agent
autotrophic	with regard to nutrition: independent of the supply of certain nutritive substances
bactericide	substance capable of destroying bacteria
bacteriophage	bacteriolytic agent produced during the growth of bacteria
biological control	pest control by means of organisms
calamity	grievous disaster
carrier	substance to which plant protection agent is bonded physically
caustic poison	poison destroying tissue and organs by its corrosive action
combined agent	plant protection product containing several active agents
contact poison	poison taking effect following contact with the same
cumulation	accumulation of agent in organism
curative	healing effect
duration of effect	period of time between application of agent and abating effectiveness
emulsion	spray liquid consisting of water and an oily liquid, the latter being finely dispersed in water
fungicide	fungi-killing agent
herbicide	weed killer
heterotrophic	feeding on dead or living organisms

ncubation	period of time between infection and appearance of disease symptoms
initial effect	beginning or immediate effect
initial toxicity	immediate effect of a poison
inorganic	inanimate
insecticide	insect-killing agent
insect	notched animal
LD 50	abbreviation for: lethal dose sufficent to obtain 50% mortality of test animals
lipoid solubility	fat solubility
metamorphosis	pronounced change
mycelium	the thallus of a fungus when it consists of hiphae
necrosis	death of cells while still part of the living body
nematicide	nematode-killing agent
nucleic acid, nucleoprotein	proteinaceous substance of cell nuclei and constituent of a virus
oral	application through the mouth, abbreviated: p.o.
organic	animate, in chemistry: compounds of carbon
organic synthetic agent	plant protection agent synthesized from carbon compounds
organism	individual animal or plant
ovicide	egg-killing agent
parasite	an organism which lives on or in another organism and derives subsistence from it without rendering it any service in return
pathogen	any disease-producing micro-organism or substance
pathological	morbid, diseased
penetrative effect	penetration of plant parts by plant protection agent
peroral, per os	see oral
permanent effect	protracted toxic effect of an agent on pests, so that specimen immigrating later are still being affected
physiology	study of the manner in which organisms carry on their life processes
phytotoxic	toxic to plants
p.p.m.	parts per million e.g. 1 mg/1 kg
prognosis	forecast
prophylaxis	preventive treatment of disease
protein, proteids	complex nitrogenous substances, which are essential constituents of living cells
range of effect	effectiveness of an agent against a number of pests or diseases
repellent	composition which, owing to its taste or smell, repels pests
residual effect	effect of a residue
residue	poison film of plant protection product on treated plants
resistant	not readily attacked by a parasite or disease
respiratory poison	poison acting by way of the breathing organs
rodenticide	rodent-killing agent
seed disinfectant	liquid or dust agent for the disinfection of seeds
selective	selecting, choice
solution	spray liquid containing agent dissolved in water without turbidity

spore	reproductive body of fungi to spread or preserve the species
stability to rain	property of plant protection product films to resist washing-off by rain for as long as possible; adhesivity of plant protection products in face of rain
stimulating	spuring on to more vigorous action
stomach poison	poison taking effect in stomach or intestines after feeding
subcutaneous	absorption through the skin
sublethal dose	quantity of poison insufficient to cause death
suspension	spray liquid consisting of a powdery substance and water; the solid particles are distributed throughout the water without settling
symptom	evidence of disease or disorder
synergism	enhanced effect due to addition of other substances
synthetic	artificially produced
systemic	agent taken up by the plant and spread throughout the plant by the vascular system
therapy	curative treatment
tolerance	permitted minimum amount of plant protection agent residue on plants and fruits
toxicity	poison effect, toxic condition
tumour	morbid growth
wetting agent	agent which does not form droplets on a surface but a coherent uniform film

SUPPLEMENT

to the series of publications on Technical Fundamentals

This supplement shows the quantitative relationship between several important British/American (Brit./U. S.) units of measure and the relevant units of the metric system of measurement. The units dealt with, here, come under the headings of

1. Linear Measures
2. Square Measures
3. Cubic Measures
4. Weights
5. Power and Work
6. Speeds
7. Temperatures

The British units of measure are also used in the U. S. A. unless exceptions are expressly stated in brackets.

The conversion tables included in this supplement are drawn up for practical use and related to British units of measure.

Abbreviations of the terms are given in brackets ( ) behind the expression when it appears in the text for the first time.

1. Linear Measures

British:

1 statute mile (mi.) = 1,760 yards
1 yard (yd) = 3 feet
1 foot (ft) = 12 inches
1 inch (in.) = 1,000 mils

Metric:

1 kilometre (km) = 1,000 metres
1 metre (m) = 100 centimetres
1 centimetre (cm) = 10 millimetres (mm)

Metric equivalents of British linear measures

1 mile = 1.609347 km
1 yard = 0.9144 m = 91.44 cm = 914.4 mm
1 foot = 0.3048 m = 30.48 cm = 304.8 mm
1 inch = 0.0254 m = 2.54 cm = 25.4 mm

Note: The decimal point placed after the unit and denoting tenths, hundreds ect. is in the German way of writing replaced by a comma.

British equivalents of metric linear measures:

1 km $= 0.621370$ mi.
1 m $= 3.281$ ft $= 39.4$ in.
1 cm $= 0.033$ ft $= 0.394$ in.
1 mm $= 0.0394$ in.

Conversion Table. Conversion of inches expressed in decimal fractions into millimetres and vice versa

in.	mm	in.	mm	mm	in.	mm	in.
0.01	0.25	4.0	101.60	0.01	0.0004	4.0	0.1575
0.05	1.27	5.0	127.00	0.05	0.0020	5.0	0.1968
0.1	2.54	6.0	152.40	0.1	0.0039	6.0	0.2362
0.5	12.70	7.0	177.80	0.5	0.0197	7.0	0.2756
1.0	25.40	8.0	203.20	1.0	0.0394	8.0	0.3150
2.0	50.80	9.0	228.60	2.0	0.0787	9.0	0.3543
3.0	76.20	10.0	254.00	3.0	0.1181	10.0	0.3937

Example: 4.687 in. = ? mm

4.0 in. = 101.6000 mm
0.6 in. = 15.2400 mm
0.08 in. = 2.0320 mm
0.007 in. = 0.1778 mm
4.687 in. = 119.0498 mm

Conversion Table. Conversion of inches expressed in proper fractions into millimetres

in.	mm	in.	mm	in.	mm	in.	mm
$^{1}/_{2}$	12.700	$^{1}/_{32}$	0.794	$^{1}/_{64}$	0.397	$^{33}/_{64}$	13.097
$^{1}/_{4}$	6.350	$^{3}/_{32}$	2.381	$^{3}/_{64}$	1.191	$^{35}/_{64}$	13.891
$^{3}/_{4}$	19.050	$^{5}/_{32}$	3.969	$^{5}/_{64}$	1.984	$^{37}/_{64}$	14.684
$^{1}/_{8}$	3.175	$^{7}/_{32}$	5.556	$^{7}/_{64}$	2.778	$^{39}/_{64}$	15.478
$^{3}/_{8}$	9.525	$^{9}/_{32}$	7.144	$^{9}/_{64}$	3.572	$^{41}/_{64}$	16.272
$^{5}/_{8}$	15.875	$^{11}/_{32}$	8.731	$^{11}/_{64}$	4.366	$^{43}/_{64}$	17.066
$^{7}/_{8}$	22.225	$^{13}/_{32}$	10.319	$^{13}/_{64}$	5.159	$^{45}/_{64}$	17.857
$^{1}/_{16}$	1.588	$^{15}/_{32}$	11.906	$^{15}/_{64}$	5.953	$^{47}/_{64}$	18.653
$^{3}/_{16}$	4.762	$^{17}/_{32}$	13.494	$^{17}/_{64}$	6.747	$^{49}/_{64}$	19.447
$^{5}/_{16}$	7.938	$^{19}/_{32}$	15.081	$^{19}/_{64}$	7.541	$^{51}/_{64}$	20.241
$^{7}/_{16}$	11.112	$^{21}/_{32}$	16.669	$^{21}/_{64}$	8.334	$^{53}/_{64}$	21.034
$^{9}/_{16}$	14.288	$^{23}/_{32}$	18.256	$^{23}/_{64}$	9.128	$^{55}/_{64}$	21.828
$^{11}/_{16}$	17.463	$^{25}/_{32}$	19.844	$^{25}/_{64}$	9.922	$^{57}/_{64}$	22.622
$^{13}/_{16}$	20.638	$^{27}/_{32}$	21.431	$^{27}/_{64}$	10.716	$^{59}/_{64}$	23.416
$^{15}/_{16}$	23.812	$^{29}/_{32}$	32.019	$^{29}/_{64}$	11.509	$^{61}/_{64}$	24.209
		$^{31}/_{32}$	24.606	$^{31}/_{64}$	12.303	$^{63}/_{64}$	25.003

Example: $3^{11}/_{16}$ in. = ? mm

3 in. = 76.200 mm
$^{11}/_{16}$ in. = 17.463 mm
$3^{11}/_{16}$ in. = 93.663 mm

Conversion Table. Conversion of feet into metres and vice versa

ft	m	ft	m	m	ft	m	ft
0.01	0.003	4.0	1.219	0.01	0.033	4.0	13.123
0.05	0.015	5.0	1.524	0.05	0.164	5.0	16.404
0.1	0.030	6.0	1.829	0.1	0.328	6.0	19.685
0.5	0.152	7.0	2.134	0.5	1.640	7.0	22.966
1.0	0.305	8.0	2.438	1.0	3.281	8.0	26.247
2.0	0.610	9.0	2.743	2.0	6.561	9.0	29.528
3.0	0.914	10.0	3.048	3.0	9.842	10.0	32.808

2. Square measures

British:

1 square mile (sq. mile) = 640 acres
1 acre = 10 square chains
1 square chain = 16 square rods
1 square rod[1] (sq.rd) = 30.25 square yards
1 square yard = 9 square feet
1 square feet = 144 square inches

Metric:

1 square kilometre (km^2) = 1,000,000 square metres (m^2)
1 square metre = 10,000 square centimetres (cm^2)
1 square centimetre = 100 square millimetres (mm^2)

Metric equivalents of British square measures	British equivalents of metric square measures
1 sq. mile = 2.5899 km^2	1 km^2 = 0.3861 sq. mile
1 acre = 4047.0 m^2	1 m^2 = 10.764 sq. feet
1 sq. yard = 0.836 m^2	1 cm^2 = 0.155 sq. in.
1 sq. foot = 0.0929 m^2 = 929 cm^2	1 mm^2 = 0.00155 sq. in.
1 sq. in. = 6.452 cm^2 = 645.2 mm^2	

Conversion Table. Conversion of sq. ft into m^2 and vice versa

sq. ft	m^2	sq. ft	m^2	m^2	sq. ft	m^2	sq. ft
0.1	0.009	6.0	0.557	0.01	0.11	6.0	64.58
0.5	0.046	7.0	0.650	0.05	0.54	7.0	75.35
1.0	0.093	8.0	0.743	0.1	1.08	8.0	86.11
2.0	0.186	9.0	0.836	0.5	5.38	9.0	96.87
3.0	0.279	10.0	0.929	1.0	10.76	10.0	107.64
4.0	0.372	100.0	9.290	2.0	21.53	100.0	1,076.39
5.0	0.465	1,000.0	92.903	3.0	32.29	500.0	5,381.94
				4.0	43.06	1,000.0	10,763.87
				5.0	53.82		

[1]) or 1 square pole (Brit. only)

Conversion Table. Conversion of sq. in. into cm^2 and vice versa

sq. in.	cm^2	sq. in.	cm^2	cm^2	sq. in.	cm^2	sq. in.
0.01	0.06	5.0	32.26	0.01	0.002	5.0	0.775
0.05	0.32	6.0	38.71	0.05	0.008	6.0	0.930
0.1	0.65	7.0	45.16	0.1	0.016	7.0	1.085
0.5	3.23	8.0	51.61	0.5	0.078	8.0	1.240
1.0	6.45	9.0	58.06	1.0	0.155	9.0	1.395
2.0	12.90	10.0	64.52	2.0	0.310	10.0	1.550
3.0	19.35	100.0	645.16	3.0	0.465	100.0	15.550
4.0	25.81	1,000.0	6,451.63	4.0	0.620	1,000.0	155.000

3. Cubic Measures

British:

1 cubic yard (cu. yd) = 27 cubic feet
1 cubic foot (cu. ft) = 1,728 cubic inches (cu. in.)
1 gallon (gal.) = 4 quarts
1 quart (qt.) = 2 pints (pt.)
1 pint = 16 fluid ounces (U. S.) = 20 fluid ounces (Brit.)

Metric:

1 cubic metre (m^3) = 1,000,000 cubic centimetres (cm^3)
1 cubic centimetre = 1,000 cubic millimetres (mm^3)
1 hectolitre (hl) = 100 litres (l) = 100,000 cubic centimetres
1 litre = 1,000 cubic centimetres

Metric equivalents of British cubic measures		British equivalents of metric cubic measures	
1 cu. yd	= 0.76453 m^3	1 m^3	= 1.308 cu. yd
1 cu ft	= 0.02832 m^3	1 m^3	= 34.314 cu. ft
1 cu. ft	= 28.317 l	1 l	= 0.0353 cu. ft
1 cu. in.	= 16.38716 cm^3	1 l	= 0.2200 gal. (Brit.)
1 gal.(Brit.)	= 4.546 l	1 l	= 0.2642 gal. (U. S.)
1 gal. (U. S.)	= 3.785 l	1 l	= 1.7598 pt. (Brit.), liquid
1 qt. (Brit.), liquid	= 1.1365 l	1 l	= 2.1134 pt. (U. S.), liquid
1 qt. (U. S.), liquid	= 0.9463 l	1 cm^3	= 0.061 cu. in.
1 pt. (Brit.), liquid	= 0.5682 l	1 mm^3	= 61.0 cu. in.
1 pt. (U. S.), liquid	= 0.4731 l		

Conversion Table. Conversion of. cu. ft into m³ and vice versa

cu. ft	m^3	cu. ft	m^3	m^3	cu. ft	m^3	cu. ft
0.1	0.003	6.0	0.170	0.1	3.53	6.0	211.89
0.5	0.014	7.0	0.198	0.5	17.66	7.0	247.20
1.0	0.028	8.0	0.227	1.0	35.31	8.0	282.52
2.0	0.057	9.0	0.255	2.0	70.63	9.0	317.83
3.0	0.085	10.0	0.283	3.0	105.94	10.0	353.14
4.0	0.113	100.0	2.832	4.0	141.26	100.0	3,531.44
5.0	0.142	1,000.0	28.317	5.0	176.57	1,000.0	35,314.45

Conversion Table. Conversion of cu. ft into l and vice versa

cu. ft	l	cu. ft	l	l	cu. ft	l	cu. ft
0.01	0.28	5.0	141.58	0.1	0.004	7.0	0.247
0.05	1.42	6.0	169.90	0.5	0.018	8.0	0.283
0.1	2.83	7.0	198.21	1.0	0.035	9.0	0.318
0.5	14.16	8.0	226.53	2.0	0.071	10.0	0.353
1.0	28.32	9.0	254.85	3.0	0.106	100.0	3.532
2.0	56.63	10.0	283.16	4.0	0.141	1,000.0	35.315
3.0	84.95	100.0	2,831.62	5.0	0.177	10,000.0	353.154
4.0	113.26	1,000.0	28,316.22	6.0	0.212		

Conversion Table. Conversion of cu. in. into cm³ and vice versa

cu. in.	cm^3	cu. in.	cm^3	cm^3	cu. in.	cm^3	cu. in.
0.01	0.16	5.0	81.94	0.1	0.006	7.0	0.427
0.05	0.82	6.0	98.32	0.5	0.031	8.0	0.488
0.1	1.64	7.0	114.71	1.0	0.061	9.0	0.549
0.5	8.19	8.0	131.10	2.0	0.122	10.0	0.610
1.0	16.39	9.0	147.48	3.0	0.183	100.0	6.102
2.0	32.77	10.0	163.87	4.0	0.244	1,000.0	61.023
3.0	49.16	100.0	1,638.72	5.0	0.305	10,000.0	610.234
4.0	65.55	1,000.0	16,387.16	6.0	0.366		

4. Weights (Avoirdupois)

British:

1 long ton (tn. l.) = 2,240 pounds = 20 hundredweights
1 short ton (tn. sh.) = 2,000 pounds
1 hundredweight (cwt.) = 112 pounds
1 pound (lb.) = 16 ounces (oz.)
1 ounce = 437.5 grains Troy

Metric:

1 metric ton (t) = 10 decitons (dt)
1 deciton = 100 kilograms (kg)
1 kilogram = 1000 grams (g)

Metric equivalent of British weights			British equivalent of metric weights
1 tn. l.	=	1.016 t = 1,016.064 kg	1 t = 0.9842 tn. l.
1 tn. sh.	=	0.9072 t = 907.2 kg	1 dt = 0.09842 tn. l.
1 cwt. (long)	=	50.8023 kg	1 kg = 2.2046 lb. = 35.274 oz.
1 lb.	=	0.4536 kg	1 g = 0.03527 oz. = 15.432 grains
1 oz.	=	28.35 g	
1 grain	=	0.0648 g	

Conversion Table. Conversion of lb. into kg and vice versa

lb.	kg	lb.	kg	kg	lb.	kg	lb.
0.1	0.05	7.0	3.18	0.1	0.22	7.0	15.43
0.5	0.23	8.0	3.63	0.5	1.10	8.0	17.64
1.0	0.45	9.0	4.08	1.0	2.20	9.0	19.84
2.0	0.91	10.0	4.54	2.0	4.41	10.0	22.05
3.0	1.36	100.0	45.36	3.0	6.61	100.0	220.46
4.0	1.81	1,000.0	435.59	4.0	8.82	1,000.0	2,204.62
5.0	2.27	10,000.0	4,535.92	5.0	11.02	10,000.0	22,046.22
6.0	2.72			6.0	13.23		

Conversion Table. Conversion of oz. into g and vice versa

oz.	g	oz.	g	g	oz.	g	oz.
0.01	0.28	5.0	141.75	0.02	0.001	5.0	0.176
0.05	1.42	6.0	170.10	0.05	0.002	6.0	0.212
0.1	2.84	7.0	198.45	0.1	0.004	7.0	0.247
0.5	14.17	8.0	226.80	0.5	0.018	8.0	0.282
1.0	28.35	9.0	255.15	1.0	0.035	9.0	0.317
2.0	56.70	10.0	283.50	2.0	0.071	10.0	0.353
3.0	85.05	100.0	2,834.95	3.0	0.106	100.0	3.527
4.0	113.40			4.0	0.141		

5. Power and work

British:

1 horsepower (h. p.) = 33,000 foot-pounds per minute (ft-lb./min)
= 550 foot-pounds per second (ft-lb./sec)

1 British Thermal Unit (B. Th. U.) = 778 foot-pounds (ft-lb.)

1 horsepower-hour (h. p.-hr.) = 1,980,000 foot-pounds = 2,545 B. Th. U.

Metric:

1 metric horsepower (PS) = 75 kilogram-metres/second = 75 kgm/s
1 kilowatt (kW) = 1000 watts (W) = 102 kgm/s
1 kW = 1.36 PS
1 kilowatt-hour (kWh) = 3,600,000 watt-seconds (Ws)

Relationship between various units

1 h. p. = 746 W = 0.746 kW = 1.014 PS
1 h. p. = 76.065 kgm/s
1 h. p.-hr. = 0.746 kWh = 1.014 PSh
1 B. Th. U. = 0.000292 kWh = 0.252 kcal
1 ft-lb. = 0.1383 kgm

1 PS = 0.986 h.p.
1 kgm = 7.231 ft-lb.
1 kcal = 3.968 B.Th.U.
1 kW = 1.34 h. p. = 44,220 ft-lb./min = 3,415 B. Th. U. per hour
1 W = 0.00134 h. p. = 44.22 ft-lb./min = 3.42 B. Th. U. per hour

Conversion Table. Conversion of h. p. into kW and vice versa

h. p.	kW	h. p.	kW	kW	h. p.	kW	h. p.
1.0	0.7	8.0	6.0	1.0	1.3	8.0	10.7
2.0	1.5	9.0	6.7	2.0	2.7	9.0	12.1
3.0	2.2	10.0	7.5	3.0	4.0	10.0	13.4
4.0	3.0	100.0	74.6	4.0	5.4	100.0	134.1
5.0	3.7	1,000.0	745.7	5.0	6.7	1,000.0	1,341.0
6.0	4.5	10,000.0	7,457.0	6.0	8.0	10,000.0	13,410.0
7.0	5.2			7.0	9.4		

6. Speeds

100 feet per minute (ft/min) = 30.5 metres per minute (m/min)
= 0.508 metres per second (m/sec)
1 mile per hour (m. p. h.) = 1.609 km/h

The speed of shafts (e. g. of a motor) is expressed in terms of revolutions per minute (r. p. m.).

7. Temperatures

Temperatures are expressed in degrees of temperature scales.

There are scales based on the following different units:

Celsius or Centigrade (C., °C)
Fahrenheit (F., °F)
Réaumur (R., °R)
Kelvin (K., °K)

Relationship: 100 °C ≙ 212 °F ≙ 80 °R ≙ 373 °K

Comparison of degrees Centigrade, Fahrenheit, Réaumur and Kelvin

C.	F.	R.	K.	C.	F.	R.	K.
− 273	− 459.4	−218.4	0	− 1	+ 30.2	− 0.8	272
− 40	− 40.0	− 32.0	233	0	+ 32.0	0.0	273
− 35	− 31.0	− 28.0	238	+ 1	+ 33.8	+ 0.8	274
− 30	− 22.0	− 24.0	243	+ 2	+ 35.6	+ 1.6	275
− 25	− 13.0	− 20.0	248	+ 3	+ 37.4	+ 2.4	276
− 20	− 4.0	− 16.0	253	+ 4	+ 39.2	+ 3.2	277
− 19	− 2.2	− 15.2	254	+ 5	+ 41.0	+ 4.0	278
− 18	− 0.4	− 14.4	255	+ 6	+ 42.8	+ 4.8	279
− 17.8	0	− 14.2	255.2	+ 7	+ 44.6	+ 5.6	280
− 17	+ 1.4	− 13.6	256	+ 8	+ 46.4	+ 6.4	281
− 16	+ 3.2	− 12.8	257	+ 9	+ 48.2	+ 7.2	282
− 15	+ 5.0	− 12.0	258	+ 10	+ 50.0	+ 8.0	283
− 10	+ 14.0	− 8.0	263	+ 20	+ 68.0	+ 16.0	293
− 9	+ 15.8	− 7.2	264	+ 30	+ 86.0	+ 24.0	303
− 8	+ 17.6	− 6.4	265	+ 40	+ 104.0	+ 32.0	313
− 7	+ 19.4	− 5.6	266	+ 50	+ 122.0	+ 40.0	323
− 6	+ 21.2	− 4.8	267	+ 60	+ 140.0	+ 48.0	333
− 5	+ 23.0	− 4.0	268	+ 70	+ 158.0	+ 56.0	343
− 4	+ 24.8	− 3.2	269	+ 80	+ 176.0	+ 64.0	353
− 3	+ 26.6	− 2.4	270	+ 90	+ 194.0	+ 72.0	363
− 2	+ 28.4	− 1.6	271	+ 100	+ 212.0	+ 80.0	373